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March 2006

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The Hayabusa spacecraft hovers over asteroid Itokawa's unusual boulder-strewn surface. p. 32

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LYNETTE COOK FOR *ASTRONOMY*

ON THE COVER

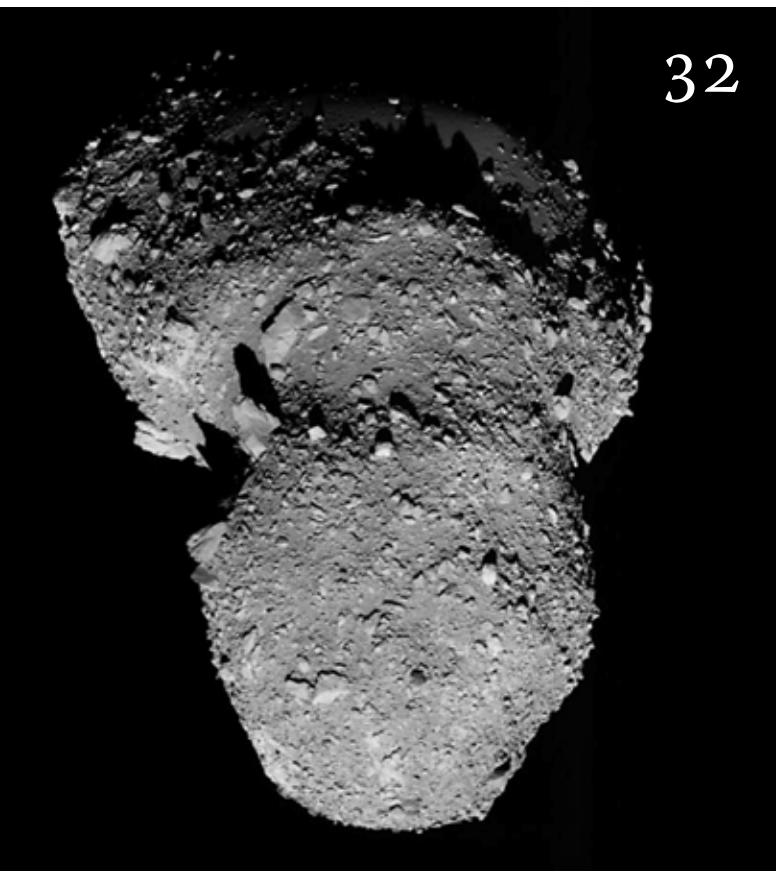
Japan's Hayabusa probe reached asteroid Itokawa last September. Despite hardware hang-ups, the probe docked with the space rock and attempted to collect the first sample from a solar system body other than our Moon. Scientists won't know whether it was successful until Hayabusa returns to Earth in 2010.

Astronomy

Observing, telescopes, origin and fate of the cosmos

VOL. 34, NO. 3

march 2006



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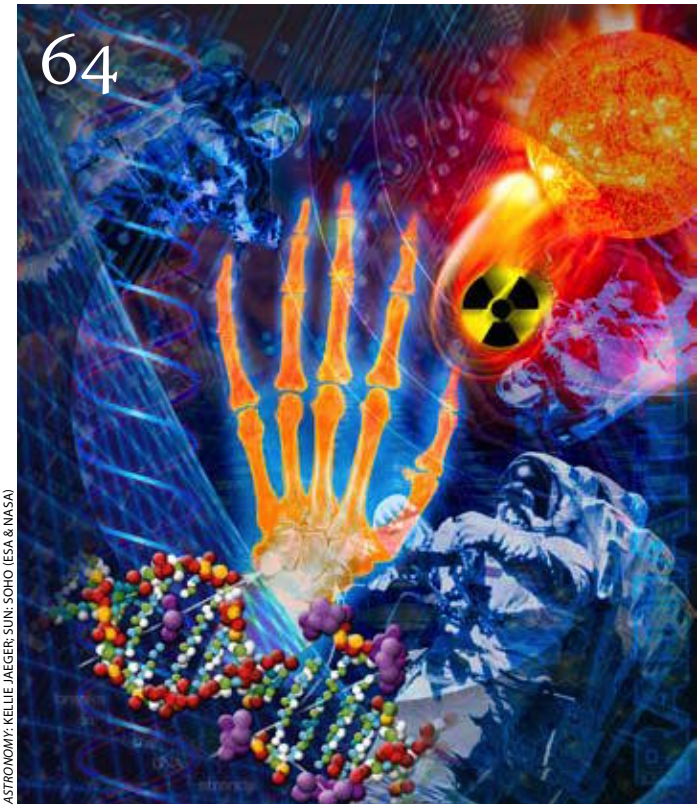

ASTRONOMY: KELLIE JAEGER; SUN: SOHO (ESA & NASA)

BY DAVID J. EICHER

Bringing back the goods

As I write this, a new chapter in space exploration is being forged. On November 25, 2005, Japan's Hayabusa probe touched down on asteroid 25143 Itokawa. Thus ended an ambitious sequence of events that aims to return pristine asteroid material to Earth for the first time.

Planetary scientists have plenty of asteroid samples by way of meteorites — some are from specific parent bodies, like 4 Vesta and 368 Haidea. But the Japanese Hayabusa mission is the first such attempt to capture and return asteroidal material to labs on Earth — a milestone in space science if the probe finishes with success.

Planetary scientist Don Yeomans brings you the full meaning of the Hayabusa mission in "Japan visits an asteroid," beginning on page 32. Yeomans details not only the mission's profile and background, but also the challenges it has faced along the way. Arriving in orbit about the Apollo asteroid (objects that pass within 1 astronomical unit of the Sun) in late September 2005, Hayabusa experienced thruster problems and had a false start attempting to touch down before achieving asteroid-fall. The Japanese Aerospace Exploration Agency believes the probe operated correctly while on Itokawa's surface, but it won't know for sure if samples were collected until the spacecraft returns to Earth in June 2007.

Venturing into the solar system has been and will remain a hazardous pursuit for humans as well as machines. With NASA aiming to return humans to the Moon and using that platform as a stepping-stone to Mars, major hazards for future spacefarers need to be considered. One of those dangers is simple dust, as veteran science writer Trudy E. Bell explores in "Warning: Dust Ahead" (page 46). Both the Moon and Mars are coated with dust that could be more dangerous than mission planners may have considered initially.

"Lunar dust is highly abrasive," Bell contends, "a talcum-fine grit of inorganic rock and powdered glass." Moon dust tracked inside the Lunar Module caused eye irritation and smelled like spent gunpowder. Astronaut Harrison Schmitt reported his nasal passages swelled shut from it. Mars dust promises to be even nastier.

Another threat permeates the solar system — radiation. In "Who knows what dangers lurk in space?" (page 64), science journalist Jacqueline Garget describes the two primary sources of space radiation: the Sun and cosmic rays, which emanate from sources in the galaxy at large. As Garget explains, astronauts who travel on a 3-year mission to Mars could be exposed to doses of radiation near the lifetime safety limits.

Whether they are most affected by continuous exposure to cosmic rays or bursts of radiation produced by the Sun's coronal mass ejections, astronauts on long missions such as those to the Red Planet would have significant cancer risks. And that's without the martian and lunar dust problem.

Before NASA pushes forward with the back-to-the-Moon-and-on-to-Mars scenario proposed by the Bush administration, it had better reconcile the dangers with the potential rewards.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 34, Number 3

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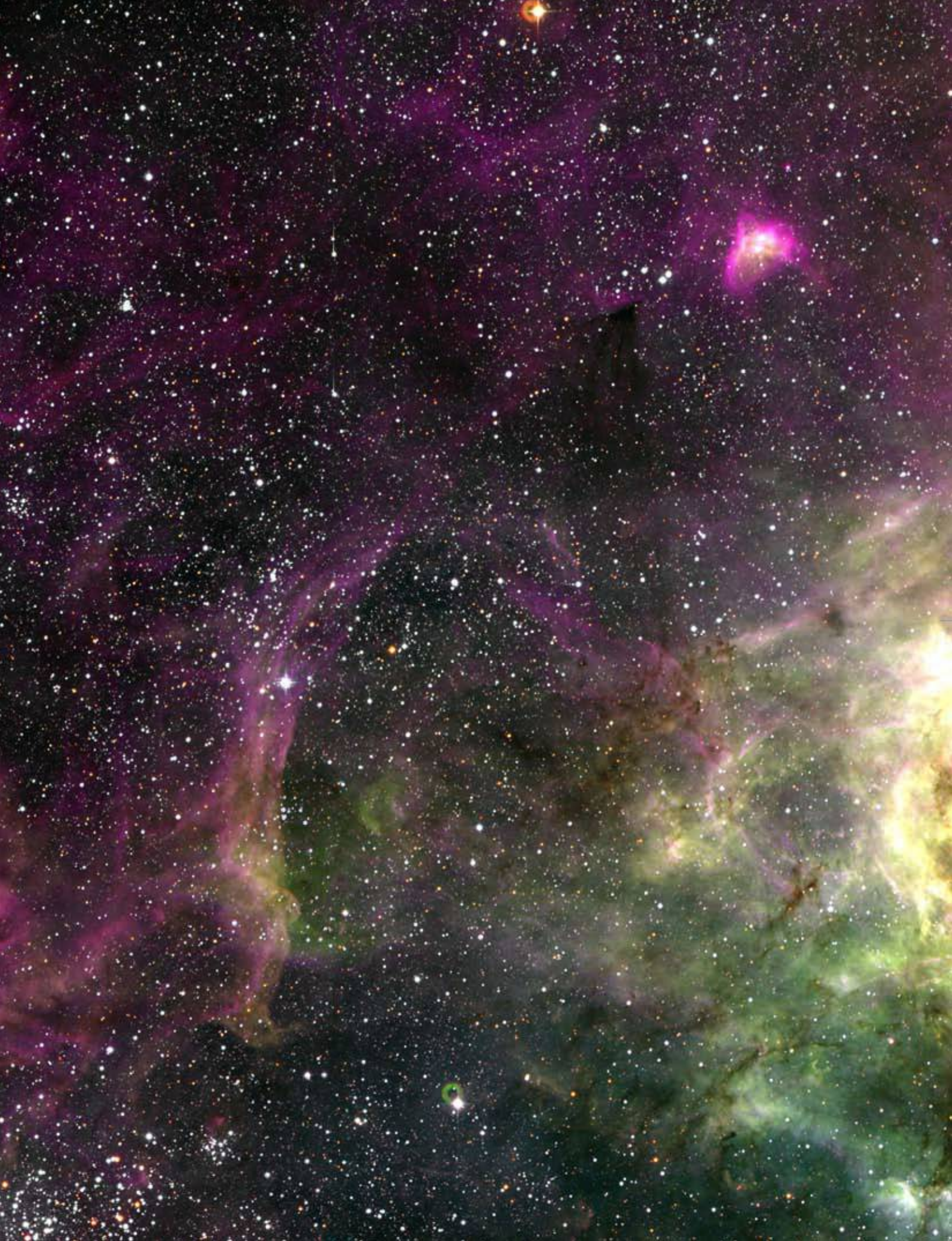

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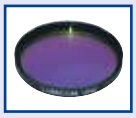

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Pluto's a planet, period

Across the Atlantic, astronomers are

fed up with the continuing debate about Pluto's status. Pluto should not lose its position as a planet. After 75 years, its atmosphere, unique double-planet status with Charon, and possible cryovolcanism still fascinate.

In fact, it should be considered *the* American Planet because it's the only planet discovered by an American. Also, Pluto's surface area (7 million square miles [11 million square kilometers]) is similar to the United States' surface area (about 6 million square miles [9 million square km]), and an American spacecraft (NASA's New Horizons) will soon visit Pluto.

The discovery of large Kuiper Belt objects doesn't affect Pluto's status, either. It is the measure by which other such planets should be judged! **— ROBERT J. BRITTON,** BRISTOL, ENGLAND

Music of the spheres

Thank you for your December 2005 cover story, "The Music of the Spheres," about the sounds of outer space. Perhaps this is what Albert Einstein had in mind when he described Wolfgang Amadeus Mozart's music as "part of the inner beauty of the universe waiting to be revealed." **— STEPHEN A. SILVER,** WALNUT CREEK, CALIFORNIA

Music to your ears

The October Forum, "Maestro of the planets," brought back fond memories of a stargazing party from my college days. Music from *Star Wars* and *Star Trek* played as we observed. A piece called "Pluto, the Renewer" by composer Colin Matthews is included on several recordings of Gustav Holst's suite. Matthews composed the piece as a tribute to Holst. **— JAMES HUDSON,** ANAHEIM, CALIFORNIA

Yerkes Observatory for sale

Yerkes Observatory is of inestimable historic value. It belongs to the scientific community, and the University of Chicago has the honor of keeping it alive as part of humanity's enduring attempt to understand the cosmos. It is not simply "property" to be auctioned off as the university deems fit. **— MICHAEL ANDERER,** ST. CHARLES, ILLINOIS

For updates on Yerkes Observatory's fate, visit www.astronomy.com/news.

R. ALBRECHT/ESO/STScI/NASA

NASA'S HUBBLE SPACE TELESCOPE captured this image of Pluto and its largest moon, Charon, in 1994. To date, it's the clearest observation available. The New Horizons mission will fly past Pluto in 2015 and send back more detailed images of the distant planet.

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***MARS,* a collector's edition from *Astronomy*, is available at local bookstores or online at www.astronomy.com.**

Mars collector's edition feedback

In the special *Mars* publication — as well as in other articles about Mars — you use "geology" many times. But the term "areology," from the Greek *Ares* for Mars, refers to the study of Mars. Why not use areology in your stories about the Red Planet? **— TOM REESOR,** CONWAY, SOUTH CAROLINA

Planetary scientists prefer the term "geology," at least when discussing the physical nature of a celestial object's surface, because it stresses that the same processes work on different objects. Volcanism, sedimentation, and erosion, just three examples, operate on many objects. Using multiple terms to describe the same thing unnecessarily confuses the matter. **— RICH TALCOTT,** SENIOR EDITOR

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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IMAGINOVA

BY BOB BERMAN

Power from nothing

Once upon a time, a vacuum meant nothing. That's changed for keeps. Most astrophysicists now believe the universe's vast tracts of emptiness seethe with unimaginable power. In a way, it all started with the ancient Greeks, who hated the notion of a vacuum. Their argument was semantic and came from their passion for logic. How could there be a vacuum, they reasoned, when "be" and "vacuum" contradict each other? It would be nonsense to believe in the existence of nothing.

In the 1960s, we assumed those silly Greeks had overthought the issue. Of course you can create a vacuum. Just evacuate all the air out of a bell jar, every last molecule, and *voilà*! Our university's best laboratory vacuums left a few atoms in place, but so what?

Turns out, the Greeks were right. First, no matter how cold and perfect the vacuum, it's still penetrated by infrared heat from the container's walls. Similarly, microwaves left over from the toasty Big Bang permeate the vacuum of space. Because energy and mass are equivalent, those waves zipping through all of space mean you can't ever have a true vacuum.

But that's technical nit-picking compared to the real antinothingness news. German physicist Werner Heisenberg's uncertainty principle, published in 1927, claims a perfect vacuum can't exist. At the time, other theorists argued empty space ought to contain a weird sort of energy.

They were correct, too. Experimental evidence shows that "virtual particles" — things like electrons and antimatter positrons — snap, crackle, and pop out of nothingness everywhere and all the time. Each particle typically exists for just a billionth of a trillionth of a second and then vanishes. If there's an energy field around, a virtual particle can borrow some of it to remain in existence forever. Thus, the seemingly empty universe forever swarms with exuberant evanescent particles, like fleas jumping up and down on a hot griddle.

Physicists now believe this underlying "quantum foam" is more than merely omnipresent: Its power is enormous. Estimates of the energy in each small bit of seemingly empty space vary greatly. It's likely the space inside a mayonnaise jar contains enough power to boil away the Pacific Ocean instantly.

It's likely the space inside a mayonnaise jar contains enough power to boil away the Pacific Ocean instantly.

Wait a second. I'm from Missouri. You'll have to prove this to me.

Okay, how about the Casimir effect? It was named for Dutch physicist Hendrik Casimir, who made an odd prediction in 1948. He said if you hang two flat metal plates very close to each other, you'd limit the vacuum power between the plates because energy waves need elbow room. That's why ocean waves don't exist in sheltered coves, and why your eyes don't boil while you stare into the microwave oven: Microwaves are too big to fit through those little holes in the screen. So the narrow gap between the plates restricts the wavelengths available for virtual particles. But the quantum energy outside the two plates is as strong as ever, and it pushes them together.

Well, this truly happens. The Casimir effect is real. Hang two plates apart by 100 times the width of an atom, and they're pressed together with a force of 15 pounds per square inch. Move them twice as close together, and the force increases 16-fold.

Some dreamers want to exploit the vacuum energy to give the world unlimited free power. Power from nothing. But there's a problem. This energy exists everywhere equally — which is why we don't sense it or detect it. Energy flows only from a place of greater energy to a place of lesser energy, just as heat moves only to where there's less of it. So how would you set up a condition that had less energy than that which is everywhere? How could you make it come to you?

The closest we get is when we chill matter to absolute zero at –459.67° Fahrenheit (–273.15° Celsius), where all molecular motion grinds to a halt. Then and only then are things at parity with this all-pervasive power. Hence, it's also known as zero-point energy.

There's evidence that this hidden geyser shows itself at that point. Helium couldn't still be liquid at absolute zero if it weren't receiving a bit of energy that keeps it from freezing solid.

So zero-point energy makes itself present when all other energy is absent. To get this limitless quantum-foam energy to flow to you, you'd have to create below-absolute-zero conditions. This means making atoms move slower than "stopped."

Slower than stopped? The Greeks surely would be scratching their heads over that one. Solve it, and the power of the universe is yours.

You'll Like What You See ...

About Vixen

Vixen astronomical products have been treating their owners to the delight of the night sky since 1949. Always respected by quality minded amateurs, Vixen today offers some of the latest technology encased in the solidity of the past. Take the "goto" SPHINX mount and STAR BOOK; a sturdy German equatorial mount for all types of scopes combined with the first electronic star chart hand-controller. The SPHINX is just one example of Vixen's ingenuity on display at Certified Stocking Vixen Dealers and in stock for you to take home and enjoy tonight.

GP-D2 Equatorial Mount

Deluxe Equatorial Mount

Geared for those seeking a portable, high-precision mount for astrophotography or simply visual observing, the GP-D2 is the perfect platform for more than just Vixen telescopes! Accurate tracking is achieved with dual 144-tooth brass worm wheels and gears. The R.A. worm is machined to 0.001 mm tolerance for accurate tracking, and all worm gears are individually inspected before assembly in Japan. Die-cast aluminum pares the weight of the GP-D2 down to 18.7 lbs. yet the design permits a carrying capacity of 22 lbs. Manual slow motion controls are provided.

R200SS 8" f/4 Richfield Newtonian

Advanced Imaging & Visual

At f/4 there's no room for error when forming the surface of a parabolic mirror. Vixen's solution is to execute each R200SS mirror with its High-Precision Poly-Order Aspherical Mirror Molding Technique. The result: exquisite state-of-the-art paraboloid form. Compact 28" length and only 11.7-lbs, the large 60mm drawtube allows for a whopping 2.6° x 1.7° field-of-view on 35mm format. The perfect imaging mate for the GP-D2 equatorial mount.

Recommended Accessories

Coma Corrector

Eliminates coma in full-frame imaging. Can be left on for visual use.

LV Eyepieces

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SPHINX mount with its Internet upgradable STAR BOOK controller, is the culmination of a decade of design experience. SPHINX responds nimbly and precisely to your commands due to its lightweight design with low-rotational momentum. STAR BOOK is striking with its 4.7" LCD screen and powerful CPU that produces localized star charts with Constellations, "goto" menus for 22,725 celestial objects: Messier, NGC/IC, Solar System, stars, and more. Auto-guider port works with SBIG guiders. Mount is controllable through popular planetarium programs such as *TheSky6* (*Serious* or *Pro*) and *Starry Nights* (*Pro* or *Pro Plus*).

The Reviews are In: "A telescope mount for the 21st century"

Astronomy magazine, November 2005

- "The Star Book is so easy to operate it flirts with user-interface perfection ... ."
- "As it stands now, the Sphinx is by far the easiest-to-use go-to mount."
- "Those interested in imaging should give this mount consideration."
- "The Sphinx is an extraordinary value because this amount of periodic error is normally encountered only in mounts 4 or 5 times its cost."
- "More good news: The mount is terrific."
- "To its credit, the screen worked well even at low temperatures — I subjected it to a test at -15° Fahrenheit (-26° Celsius) one night... ."

Recommended Accessories

Polar Axis Scope

6x20mm

for both hemispheres

Aluminum Case

Holds SPHINX, STAR BOOK, weights, battery case and more.

Tripod Carry Bag

Includes half-pillar pouch.

PORTA Alt-Az Mount

PORTA: Exceptionally Portable Mount!

Newly designed friction system for quickly pointing toward the object and hand tracking it with the 360° slow-motion controls. No fumbling with clutches or sectional slow-motion controls! Leave the counter-weights with the equatorials: simply balance scopes up to 9-lbs. on the altitude axis and start viewing! Standard Vixen dovetail mounting slot with lock and safety screw is fully SPHINX/GP-compatible. PORTA mount features interchangeable slow-motion knobs, tension adjustment and disassembly tools, built-in tool storage bay, tripod tray and aluminum legs.

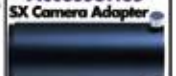
ED80Sf 80mm f/7.5 APO Refractor

Portable Affordable APO

Breakthrough price on an ED80Sf scope package including giant 9x50mm finder, dual T-thread flip-mirror with 1¼" eyepiece adapters, rotatable 2" eyepiece adapter with locking collar, Crayford focuser with tension/lock adjustment, tube rings with dovetail plate and telescope/accessory travel case! Included standard accessories make the ED80Sf the value leader in affordable 80mm APO scopes. Perfect size for PORTA mount makes this an exceptionally portable system.

Recommended Accessories

SX Camera Adapter



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BY GLENN CHAPLE

Lunar spectacular

Have you ever gazed in spellbound

silence at an aurora, admired the spangled beauty of the Pleiades, or pondered the mystical blue-green glow of a planetary nebula? By whatever means — unaided eyes, binoculars, or a telescope — a visual stroll through the night sky brings you face-to-face with some strange and amazing sights. It's easy to feel like Alice adrift in a cosmic Wonderland, particularly when you encounter the Cheshire-cat grin of a crescent Moon.

March offers favorable conditions for viewing a waxing (visually growing) crescent Moon. The angle between the ecliptic (the pathway traversed by the Sun across the starry background) and the western horizon is particularly high at sunset now. Thus, Sun-hugging objects, like a "young" crescent Moon and the inner planets Mercury and Venus during their evening-sky forays, rest high above the setting Sun.

Now is the time when Moon-watchers try for a glimpse of a young Moon — one that is roughly 1 day past new phase. Your best dates to see a day-old crescent are February 28 and March 30. You'll need an observing location that affords a low, open western horizon. Skies must be clear — low-lying haze will conceal the Moon.

> "Well, I've seen a cat without a grin," thought Alice; "but a grin without a cat! It's the most curious thing I ever saw in all my life!"
>
> *Alice in Wonderland* – Lewis Carroll

JAY OUELLET

EARLY EVENING EARTHSHINE accompanies a young Moon's Cheshire cat-like grin. Try between March 1 and 3 to see both phenomena.

Begin your search 10 to 15 minutes after sunset. The Moon will be no more than 10° above the horizon (remember, the Full Moon appears ½° wide), so concentrate on the area above and slightly left of the point on the horizon where the Sun set. If your unaided eyes fail to capture the Moon, try using binoculars. A young Moon will appear as a glimmering hairline curve, barely visible in the evening twilight.

The waxing crescent Moon most casual observers notice appears between 2 and 4 evenings after New Moon. We'll have two opportunities this month to enjoy an early evening audience with this "Cheshire cat" Moon — the 1st through the 3rd, and again from March 31 through April 2.

As the sky darkens, you'll notice there's more to the crescent Moon than just a luminous grin. The "dark" part of the lunar disk appears awash in a ghostly glow. You're looking at earthshine, also known as "the old Moon in the New Moon's arms." Your unaided eyes can spot earthshine, especially when a branch or rooftop masks the bright crescent. Binoculars or a small telescope really shows it off.

What causes earthshine? Leonardo da Vinci explained it 5 centuries ago. A master at understanding the interplay of light and shadow, he reasoned that sunlight reflected from Earth illuminates the lunar surface. He understood that, viewed from a crescent Moon, Earth would appear as a dazzling, nearly full orb. The nighttime lunar landscape would be bathed in brilliant earthlight — the light we see as earthshine.

Because earthshine is a reflection of Earth's atmospheric conditions, its intensity varies. Clouds reflect more sunlight than land or sea, so a cloudy Earth produces a more prominent earthshine than a fair-weather Earth. Earthshine diminishes as the Moon's crescent widens and brightens.

March is Messier marathon month. I'll be "duking it out" with Phil Harrington again. For the past 2 years, clouds have scuttled the event here in the Northeast. Last year, I tried a make-up marathon in April. Final tally: 98 "kills." I'll have to do much better this year if I want to beat the Binocular Man — especially now that I've learned the secret to his Messier marathon success.

Around sunset on a Messier marathon evening, Phil drives out to his dark-sky site on Long Island. On the side of a barn, he tacks up a poster depicting all of the Messier objects. Once evening darkness sets in, he illuminates the poster with a lantern, then trudges to a spot 100 yards away. He scans the chart with his binoculars, dutifully checks off everything on his Messier list, then packs up and heads home for a good night's sleep. When Phil says he was "clouded out," he really means the batteries to his lantern failed!

Next month: Will the Cheshire cat devour the Pleiades? Plus, it's party time — astronomically speaking.

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He has received citations from institutions such as MIT and the University of Chicago for being named "most influential teacher" by attending students.

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He is the recipient of numerous teaching awards. Included are the Davidson Award, a Presidential Award for Science Teaching, the National Catalyst Award for Outstanding Chemistry Teaching, and the National James Bryant Conant Award. The latter two are given to only one high school chemistry teacher in the entire United States each year.

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BY PHIL HARRINGTON

Visit the Charioteer

Head outside this evening, and take

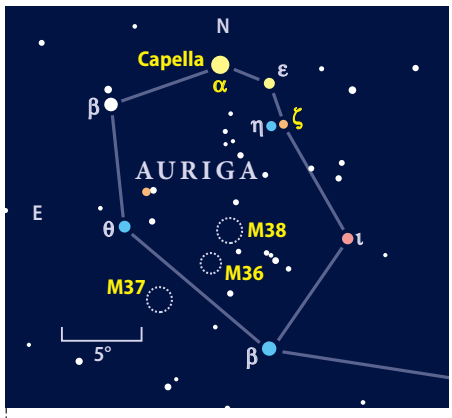
a look overhead. If you live in mid-northern latitudes, you will find a lone beacon cresting near the zenith — the point in the sky straight overhead — as the sky darkens. Capella lies in Auriga the Charioteer and marks one of seven points in the winter oval of stars. Tracing back to ancient Rome, the name **Capella** translates to "She-Goat," a reference to the position it holds in the Charioteer's picture. He is usually shown holding a goat and two kids in his arms.

Today, we know Capella is a binary star system lying about 42 light-years away. Each of Capella's suns is classified as a type-G yellow star, like our Sun. All three have similar surface temperatures, but our dwarf Sun is about one-tenth as large as either of the Capella giants. Spotting the two component stars through even the largest telescopes can be difficult. Only 60 million miles (97 million kilometers) — less than the distance between the Sun and Venus — separate the two.

Just south of Capella lie three 3rd-magnitude stars in the shape of an isosceles triangle. Often referred to as "The Kids," this trio represents two young goats held by Auriga. They glisten beautifully through binoculars. Two shine pure white, while the third, **Zeta (ζ) Aurigae**, appears orange.

Hop a little more than a binocular field south of, or below, the triangle to see a neat little pattern of five faint stars. Four form a parallelogram, while the fifth lies just below. This isn't a star cluster, but an asterism — one of those fun shapes you bump into every now and again.

Given March's windy days, the pattern reminds me of a box kite with a tail being whipped about. With your unaided eyes from a dark site, you might see the kite's oblong glow slightly west of the constellation's center.



USE THIS FINDER CHART to scour Auriga the Charioteer. *ASTRONOMY:* ROEN KELLY

Look just above, or north of, the box kite for a dim glow among the stars. That's **M38**, one of Auriga's three Messier open clusters. Giovanni Batista Hodierna (1597–1660), astronomer at the court of the Duke of Montechiaro in Sicily, discovered all three through a 1-inch refractor around the year 1654. Don't be surprised if you can't see M38 at first through your 21st-century binoculars, however. This cluster can be tough to pick out from among the surrounding stars.

While looking for M38, you might notice **M36**, a second fuzzy glow snuggled between two faint field stars about half a binocular field to the east. M36 is smaller and more condensed than M38, so you should be able to spot it more easily. If you have good eyes and 70mm or larger binoculars, you might see a few faint stars peering back at you. Telescopes reveal that the cluster's brightest stars fall into a pattern resembling a crooked Y.

The third and brightest Messier open cluster in Auriga, **M37**, rests about a binocular field east of M36. Because its brightest stars shine at only 9th magnitude, M37 appears as a faint, misty patch of light through binoculars.

March is traditionally the best month to spot all 109 Messier objects in a single dusk-to-dawn observing session. The Sun's position in the sky around the vernal equinox March 20 leaves all but M30 in view sometime during the night. For strategies and suggestions, read my article "Messier marathon: ready, set, go" on Astronomy.com. Also, check out *Astronomy* Associate Editor Michael E. Bakich's "Take a deep-sky treasure hunt" on page 74. This year, the Moon stays out of the way the weekend of March 25, so that's prime time.

Astronomy columnist Glenn Chaple has challenged me the last few years to run the marathon against him. He knows he can't win, but clouds have let him save face. You'll have nowhere to hide this year, Chaple! I'm ready for you, armed with my trusty 10x50 and 16x70 binoculars.

My best binocular marathons were 85 objects through a pair of 7x35s in the 1980s and 101 through 11x80s some years later. How about you, dear reader? Care to join us? E-mail me at phil@philharrington.net after the marathon to let me know how you made out. I'll publish the best binocular tallies in a future column.

Next month, we celebrate spring by visiting two of the season's finest binocular star clusters. Till then, remember: Two eyes are better than one!

ONLINE EXTRA Before you start your Messier marathon, download a PDF of Phil Harrington's "Messier marathon: ready, set, go" (March 2002) at www.astronomy.com/toc.

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Weigh in Astronomers using the Hubble Space Telescope have "weighed" Sirius B, the white-dwarf companion to Sirius, the brightest star. Sirius B has 98 percent of our Sun's mass.

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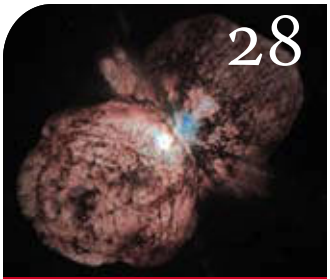
Astronews

NASA/JPL-CALTECH/R. A. GUTERMUTH (HARVARD-SMITHSONIAN CfA)

WILD YOUTH. Outflows from NGC 1333's newest stars create intertwined shock fronts (green) in this Spitzer Space Telescope image.



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30 New Einstein rings

Stellar jets stir NGC 1333

When astronomers used NASA's Spitzer Space Telescope to spy on two young star clusters in the reflection nebula NGC 1333, they uncovered a surprising number of nebulous streaks, shown as green in this false-color image.

The streaks are shock fronts set aglow when jets of gas streaming from the nebula's youngest members slammed into cold gas. "The sheer number of separate jets that appear in this region is unprecedented," says Alicia Porras of the Harvard-Smithsonian Center for Astrophysics. "Untangling them will prove quite a challenge as we try to identify which protostar is the source of each jet."

One of the young clusters lies to the north, near a patch of warm dust (red), while the other is in the south, near the green shocks. "With the sharp infrared eyes of Spitzer, we can look for differences between these two groups of stars," Porras says. "The results could reveal hints of the star-forming history of this region."

About 80 of NGC 1333's young stars are surrounded by dusty disks that may harbor planets. The nebula, located in Perseus about 1,000 light-years from Earth, is home to stars less than a million years old. By clearing out the gas, the jets may eventually bring star formation to a halt. — **FRANCIS REDDY**

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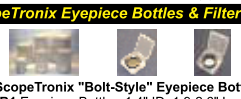

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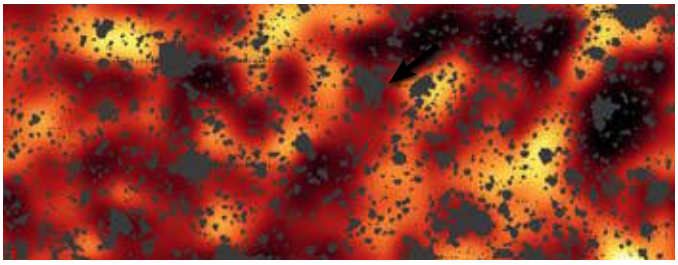
Mars aurorae

Mars Global Surveyor electron-energy measurements show that hundreds of ultraviolet aurorae occurred in Mars' atmosphere during the past 6 years.



NASA/JPL-CALTECH/A. KASHLINSKY (GSFC)

AFTERGLOW. A diffuse infrared background (color) remained in this Spitzer view after scientists subtracted known sources (gray).

Has Spitzer sensed the first stars?

Scientists using NASA's Spitzer Space Telescope claim they've detected the faint glow of the first stars. The earliest stars were at least 100 times our Sun's mass and exploded as supernovae just a few million years after their births. The stars are long gone, but their ultraviolet light — now stretched into near-infrared wavelengths by cosmic expansion — lives on.

"We think we are seeing the collective light from millions of the first objects to form in the universe," says Alexander Kashlinsky of NASA's Goddard Space Flight Center. Kashlinsky is the lead author of the study, which appeared in *Nature* November 3, 2005.

Scientists think radiation from the first stars makes up a large part of the Cosmic Infrared Background (CIB). An infrared background remained when the group subtracted all known infrared sources from a 10-hour exposure of a region in Draco. — **LIZ KRUESI**

A flare for Barnard's Star

Diane Paulson of NASA's Goddard Space Flight Center in Greenbelt, Maryland, and her colleagues report Barnard's Star unleashed a flare July 17, 1998. The flare's temperature was at least 8,000 kelvins, more than double the star's 3,100-kelvin surface temperature, and it resembled those from young, fast-spinning red dwarfs. The trouble is, Barnard's Star is roughly 11 or 12 billion years old and rotates at the stately pace of once every 130 days.

William Cochran at the University of Texas, Austin, obtained the star's spectrum during its 1998 flare-up. Paulson's recent analysis makes it clear that Barnard's Star experienced an event similar to those seen in younger red dwarfs.

NASA/JPL-CALTECH/B. WELSH

FLARE UP. More than twice our Sun's age, Barnard's Star flares like younger red dwarfs, such as GJ 3685A (center).

The find means all three of the nearest red dwarfs are flare stars: Proxima Centauri, the faintest member of the Alpha Centauri system; Barnard's Star; and Wolf 359 in Leo. Paulson and her colleagues will publish their work in a future issue of *Publications of the Astronomical Society of the Pacific*. — **KEN CROSWELL**

Scars from a violent past

Asteroids, not comets, bombarded the inner solar system 3.9 billion years ago, according to a study published in the September 16, 2005, issue of *Science*. Robert Strom of the University of Arizona's Lunar and Planetary Laboratory in Tucson led a team that examined cratering records on the Moon, Mercury, Venus, and Mars.

ESA/SPACE-X

BATTERED. Main-belt asteroids roughed up the Moon, shown here, and inner planets 3.9 billion years ago.

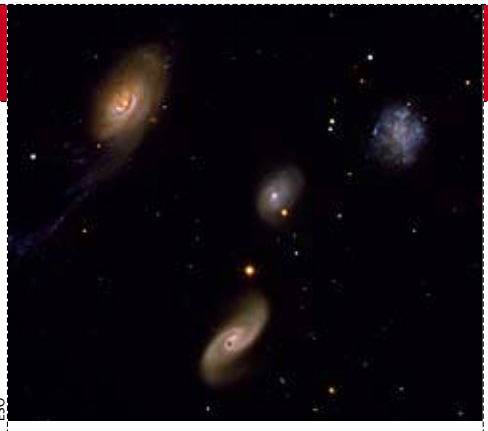
"There is a direct translation from the size of craters to the size of their impactors," explains team member Renu Malhotra. "The population of main-belt asteroids matches the complex, densely cratered surfaces almost perfectly." The cratering record for the first bombardment — as seen, for example, in the Moon's rugged highlands — fits an asteroid source far better than a cometary one.

Moreover, a different asteroid population struck younger surfaces, such as lunar maria. "[T]he distribution of near-Earth asteroids [NEAs] matches the younger surfaces beautifully," Malhotra says. While NEAs also originate from the main asteroid belt, their impact rate amounts to a gradual rain of rock compared to the initial heavy bombardment, which may have lasted anywhere from 20 to 150 million years.

The authors think the heavy bombardment followed a relatively quiescent period after the planets finished accreting from gas and dust around the Sun. "The event must have happened fairly quickly, due to a major dynamic instability in the asteroid belt," Malhotra explains. Exactly what triggered this instability remains a mystery. — **MICHAEL CARROLL**

Ice bugs

Methane-producing microbes found at the bottom of Greenland's ice sheet suggest Mars' methane could arise the same way.



ESO

4-RING CIRCUS. The compact galaxy group known as Robert's Quartet glows collectively at 13th magnitude in Phoenix.

Family circus

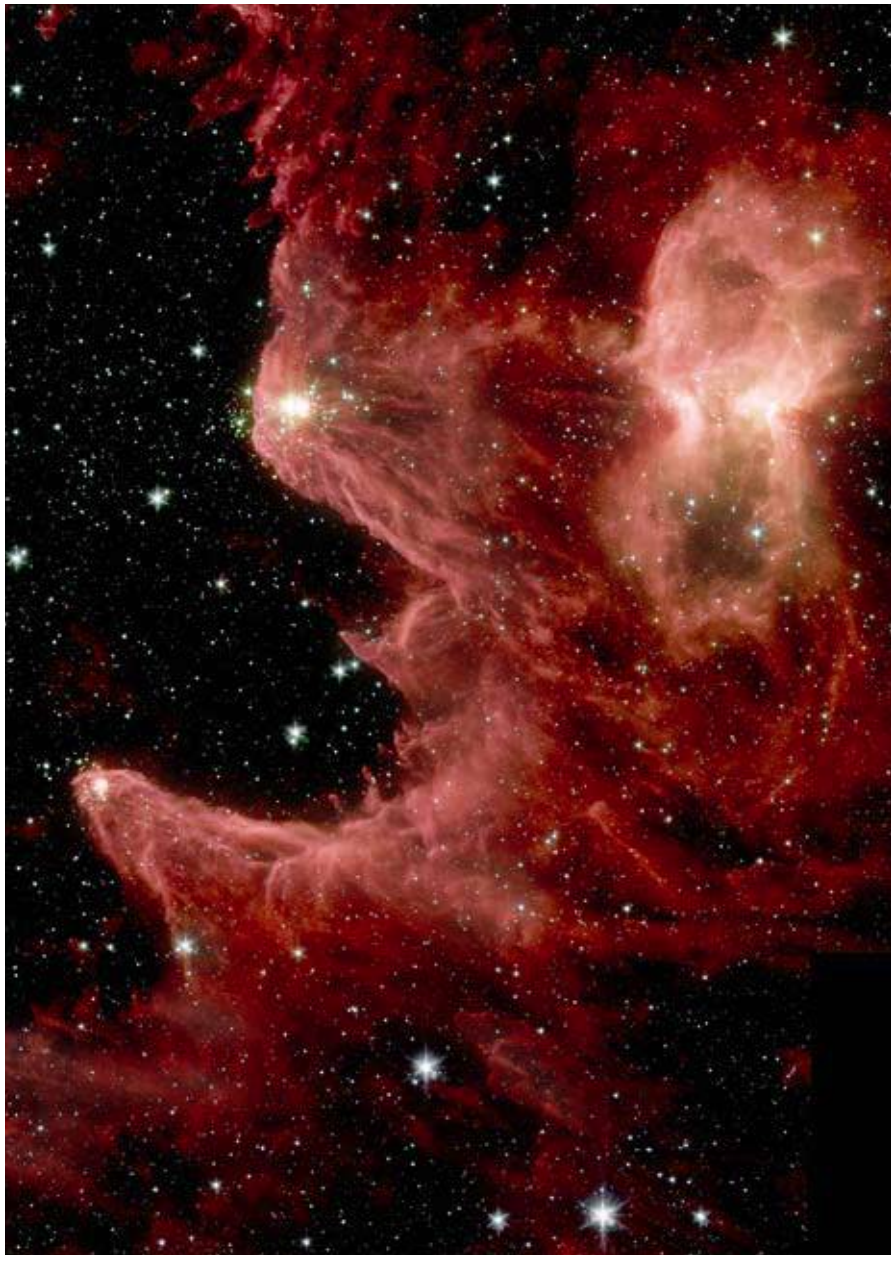
Astronomers using the European Southern Observatory's Very Large Telescope in Chile imaged a family of four galaxies known as Robert's Quartet. This compact group is located about 160 million light-years away in the southern constellation Phoenix. Such compact galaxy groups usually contain four to eight galaxies in a small area of the sky — Robert's Quartet covers 1.6′ — and provide astronomers with a perfect realm for studying galaxy interactions and star formation. — **L. K.**

ESA

SUPPLY SHIP. The ESA craft won't launch before May 2007.

Jules Verne delayed

Jules Verne, the European Space Agency's Automated Transfer Vehicle, is considered the most complex spacecraft ever developed in Europe. It was slated for launch this year until technicians discovered metal fatigue on rods that open and close fuel valves, and problems with the craft's solar-array drive mechanism. The fixes forced ESA to push Jules Verne's inaugural flight to May 2007. For this mission, the 19-ton unmanned vehicle is scheduled to deliver 7 tons of supplies to the International Space Station. — **F. R.**



NASA/JPL-CALTECH/L. ALLEN AND J. HORA (CfA)

SLAM-BAM STAR CLOUD. Strong radiation and outflows from a single star (out of image, left) may have given rise to young clusters embedded in W5's dusty pillars.

Cold mountains of dust

Fingerlike pillars of cold dust point toward the single, massive star that dominates W5, a star-forming region 7,000 light-years away in Cassiopeia. NASA's Spitzer Space Telescope peered through the dense dust to reveal never-before-seen stars within it.

The massive star's intense radiation and violent outflows blast the cloud's material outward; only the densest clumps remain. "It appears that radiation and winds from the massive star triggered new stars to form," says Lori Allen of the Harvard-Smithsonian Center for Astrophysics, in Cambridge, Massachusetts. "We believe that the star clusters lighting up the tips of the pillars are essentially the offspring of the region's single, massive star." — **L. K.**

NASA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

GLOBULAR GAS. M15 holds the first interstellar gas ever found in a globular cluster.

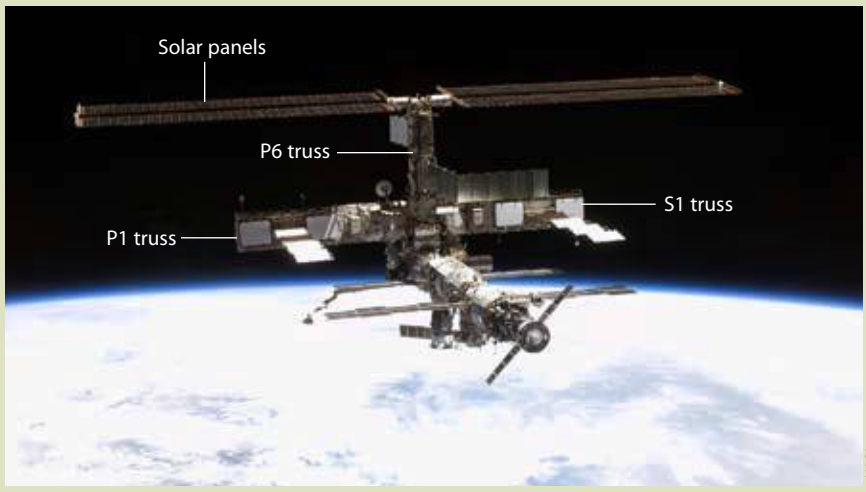
A globular's interstellar gas

A team led by Jacco van Loon and Aneurin Evans, both of Keele University in England, has tentatively detected neutral hydrogen gas in M15. It would be the first interstellar gas ever found in a globular cluster. M15 lies some 34,000 light-years away in Pegasus.

Using the Arecibo radio telescope, the astronomers detected radio waves in M15 that are the hallmark of neutral atomic hydrogen. But the amount — a paltry 0.3 solar mass — falls far short of theoretical expectations. A globular cluster's red giants should produce roughly 100 solar masses of gas before the cluster crosses the Milky Way's plane, an event that strips gas from the cluster.

So, where did M15's gas go? Van Loon and his colleagues suggest radiation pressure from M15's starlight may push gas out of the cluster. And, as M15 cruises through our galaxy's halo, collisions with any gas there might also strip gas away from the cluster.

Van Loon's group may have detected neutral atomic hydrogen gas in two other globulars — M2 in Aquarius and Palomar 13 in Pegasus. The team will publish its work in a future issue of *Monthly Notices of the Royal Astronomical Society*. — **K. C.**



NASA

GROWTH SPURT. Extending ISS will begin when regular shuttle flights resume.

Space station set to grow

The International Space Station (ISS), the gleaming jewel of America's manned space program, is about to get brighter.

For the past 5 years, skywatchers using prediction information available over the Internet have watched ISS' stately progression through the sky at dusk or dawn. Some imagers have even resolved individual modules and panels.

The ISS spectacle is about to increase in magnitude — literally. NASA will resume assembly of the orbital outpost toward the end of this year, once the space shuttle fleet is recertified. Planned construction will quadruple the surface area of the station's solar panels. This, in turn, will lead to a brightness increase of more than 1 magnitude. They'll also provide more opportunities for brief, brilliant reflections of sunlight off the arrays.

ISS now consists of a string of pressurized modules attached end-to-end beneath a crosswise truss. This truss carries extra equipment, like solar arrays and thermal radiators. There's hardware already built that will add to the truss' ends. Each end will house new experiments, many of which come with their own solar arrays.

A U.S. module already connects to one element, the so-called P6 (port-side) truss. NASA will move it to the end of the main truss after the agency deploys other new segments.

ISS began its existence in late 1998 as a Mir-class station supplied with the modest solar arrays characteristic of Russia's space stations. After a permanent crew attached the P6 array in late 2000, ISS brightened considerably. During the next 2 years, more missions added pressurized modules and truss segments to the port (P) and starboard (S) ends, but these additions didn't make the station look any brighter.

Astronauts attached the truss' center section (S0) atop the U.S. Destiny lab in April 2002. They followed this with additional construction: the S1 segment in October 2002 and the P1 truss the following month.

But that's where assembly stalled.

Hardware destined for ISS has been stacking up in storage at the Kennedy Space Center in Florida. Shuttle missions in 2006 and 2007 will carry this equipment to ISS. Mission 12A will carry the P3/P4 truss; 12A.1 will bring the P5 truss; 13A will deliver the S3/S4 truss; and mission 13A.1 will loft the S5 truss. A later flight will carry the S6 segment, and, on a subsequent mission, P6 will be moved to its permanent location at the far end of the station's port-side truss.

The truss structure provides physical separation for ISS' large power-generating solar arrays. It also houses equally important radiators, which dump waste heat into space. Other equipment, as yet undesigned, will be mounted as the completed station orbits into future decades.

And as ISS continues to grow, skywatchers will marvel at the dazzling dot cruising through the sky above. — **JAMES OBERG**

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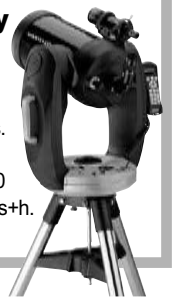

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NASA/JPL/SSI

IN THE GROOVE. **Multiple generations of fractures cut across Dione's rugged terrain.**

Cassini rushes past Dione

On October 11, 2005, NASA's Cassini spacecraft flew within 310 miles (500 kilometers) of Saturn's fourth-largest moon, Dione. This marked the probe's only close pass by the heavily cratered world.

Craters dominate the surface of this 696-mile-diameter (1,120 km) moon just as they do on most of Saturn's satellites, but Dione has a style all its own. Tectonic activity cracked the moon's surface many times during its history. Bright, braided canyons make up Dione's striking, wispy terrain — first imaged by the twin Voyager spacecraft in the early 1980s. Many fine, roughly parallel grooves in the moon's southern hemisphere crisscross all other terrain types. This suggests they're the moon's youngest features.

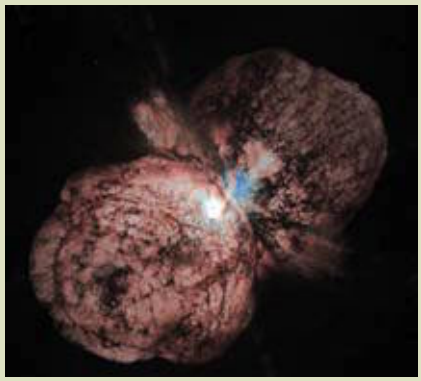
Cassini's instruments found conspicuous brightness variations across Dione's surface, which consists largely of frozen water. These changes possibly indicate where rock slides have exposed fresher, cleaner ice. — **RICHARD TALCOTT**

FUSE finds Eta Carinae's companion

Astronomers using the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite have directly detected a companion orbiting the star Eta Carinae. One of our galaxy's most massive and peculiar stars, Eta Carinae, which lies 7,500 light-years away, has been intensely studied for decades.

"Until now, Eta Carinae's partner has evaded direct detection," says Rosina Iping, a research scientist at Catholic University of America in Washington. "This discovery significantly advances our understanding of the enigmatic star."

The star orbits about as far from Eta Carinae as Saturn does from our Sun. A cyclic, 5.5-year variation in the star's infrared, radio, light, and X-ray outputs has long suggested the companion's presence. Using FUSE, Iping and her collaborators observed far-ultraviolet light from Eta Carinae that vanished as an expected drop in X rays occurred. The astronomers conclude Eta Carinae eclipsed the star. The team's work appears in the November 1, 2005, *Astrophysical Journal Letters*. — **F. R.**



NASA/JON MORSE (UNIVERSITY OF COLORADO)

PARTNER FOUND. **Eta Carinae (center) has a stellar companion.**

BRIEFCASE

The Milky Way's compact source

The radio source at our galaxy's center, called Sgr A* and believed to be a black hole, is so small it would fill only the space between Earth and the Sun. Astronomers obtained the first high-resolution image of Sgr A* at a wavelength of 3.5 millimeters using the Very Long Baseline Array. The team reported its observations in the November 3, 2005, issue of *Nature*. — **F. R.**

Record meteorite

Meteorite-hunter Steve Arnold hit pay dirt in October 2005, when he unearthed a 1,400-pound (635 kilogram) meteorite on a farm in Haviland, Kansas. The rock, a cone-shaped oriented pallasite, is the third largest of its type known. The farm's owners will share in the proceeds when the rock sells. Its estimated value: $1 million plus. — **F. R.**

Is Einstein's "blunder" right after all?

In 1917, Albert Einstein added a fudge-factor to general relativity in order to balance the attractive force of gravity. After Edwin Hubble showed the universe is actually expanding, Einstein retracted his cosmological constant, which he called his greatest blunder. Now, a survey of distant supernovae reveals that dark energy — the mysterious force accelerating cosmic expansion — behaves like Einstein's constant to a precision of 10 percent.

"Our particular observation is at odds with a number of theoretical ideas about the nature of dark energy. They generally predict that it should change its form as the universe expands," says University of Toronto's Ray Carlberg. "[A]s far as we can see, it doesn't."

Carlberg is part of the Supernova Legacy Survey (SNLS), a collaborative international effort that uses the 3.6-meter Canada-France-Hawaii Telescope atop Mauna Kea, Hawaii, and its giant MegaCam imager. Researchers first identify distant supernovae in MegaCam images. Then they acquire the exploding stars' spectra using some of the largest telescopes on Earth, including the Gemini North and Keck telescopes on Mauna Kea.

The initial results, to be published in an upcoming issue of *Astronomy & Astrophysics*, are based on about 20 nights of data, the first of over 200 nights slated for the project. Scientists expect future results will double or even triple the finding's precision. — **F. R.**

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ESO ART

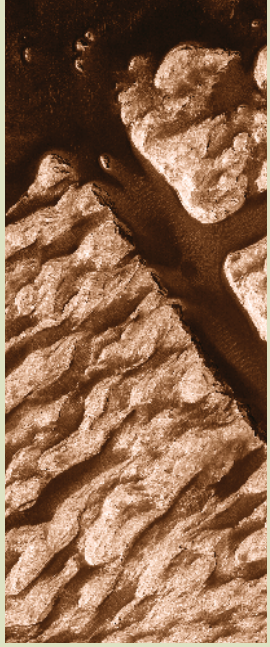
RUNAWAY. Star HE0457–5439 was shot out of the LMC.

Stellar speedster

A team led by Heinz Edelmann at the University of Texas, Austin, has found a massive, young star speeding through the Milky Way's halo at more than 1.6 million mph (2.6 million km/h). Astronomers estimate the star, known as HE0457–5439, is 30 million years old — too young to have formed among our galaxy's oldest stars.

If shot from the central Milky Way, says the team, the star would have to be 3 times older to reach its present position. "Either the star is older than it appears or it was born and accelerated elsewhere," says team member Uli Heber of the University of Erlangen-Nürnberg, Germany.

In fact, the star lies close to the Large Magellanic Cloud (LMC), a Milky Way satellite. The astronomers suspect HE0457–5439 was ejected from the LMC after a close encounter with a black hole there accelerated the star to breakneck speed. The study appeared in the December 1, 2005, issue of *Astrophysical Journal Letters*. — **L. K.**



NASA/JPL/MSSS

HIGH CONTRAST. "White rock" is a Mars landmark.

Pollack Crater's "White Rock"

On Mars, a light patch of rock on Pollack Crater's floor contrasts so greatly with the crater's dark sand that scientists in the 1970s named it "White Rock." This image from Mars Global Surveyor's Mars Orbiter Camera shows a portion of the feature. The light-colored materials are probably the remains of layered sediments that once completely covered the crater's interior, but slowly eroded away. — **F. R.**

NASA/JPL/ASU

ABOVE THE REST. This odd crater on Mars' Utopia plains stands on high ground.

Crater on a pedestal

An unnamed martian impact crater in a false-color Mars Odyssey image looks as if it were placed on a pedestal. Located in the northern plains of Utopia, the crater is about 2.6 miles (4.2 kilometers) wide and about 600 feet (200 meters) deep. It stands on a rocky platform some 200 feet (60m) above the surrounding plain. Scientists think the pedestal formed from the impact's ejecta apron, which reinforced the ground against later erosion. — **F. R.**

New set of rings

Astrophysicists have identified 19 new gravitationally lensed galaxies, eight of which are new Einstein rings. Previously, astronomers knew of only 100 lensed galaxies and three visible-light Einstein rings.

Researchers using the Sloan Digital Sky Survey (SDSS) found possible lensing candidates and then used the Hubble Space Telescope's Advanced Camera for Surveys (ACS) for confirmation. The project is part of an ongoing program called the Sloan Lens ACS Survey (SLACS).

NASA, ESA, A. BOLTON (HARVARD-SMITHSONIAN CFA), SLACS TEAM

PERFECT CIRCLE. Foreground galaxies warp light from background galaxies into rings.

Massive objects warp space around them. So, when light passes close to such an object — a massive elliptical galaxy or a galaxy cluster — the light's path bends, and the object acts as a lens. If a galaxy sits directly behind a massive object from our viewpoint on Earth, the light forms a ring around the foreground galaxy. Such an image is known as an Einstein ring. If the objects are not precisely aligned, an observer will see the background galaxy as a series of arcs instead of a continuous ring.

The foreground galaxies contain more mass than their luminous material suggests, which gives researchers insight into dark matter's distribution. The study appears in a February issue of *The Astrophysical Journal*. — **L. K.**

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Japan visits an asteroid

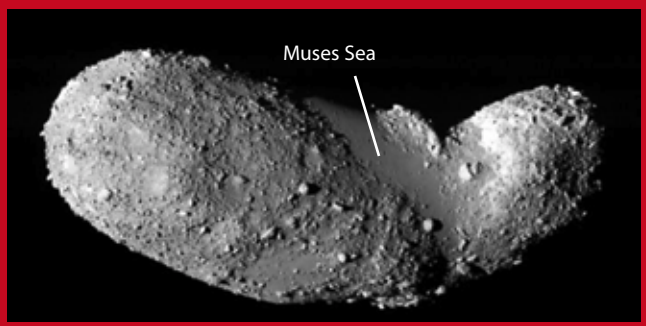
The Hayabusa probe revealed how different space rocks can be when it visited boulder-strewn asteroid Itokawa. /// BY DON YEOMANS

Last September, news that a Japanese spacecraft had arrived at asteroid Itokawa and was flying formation with it came as a surprise to many, including some planetary scientists. Refrigerator-size Hayabusa (Japanese for falcon) stayed out of the limelight until its cameras scanned the asteroid's boulder-strewn surface like a raptor eyeing its intended prey. The probe's bold mission: Descend to Itokawa, capture dust from its surface, and return the sample to Earth for analysis. If successful, it would be the first surface sample collected from a solar system body other than the Moon.

Hayabusa's scientific goal is to advance our understanding of Earth's closest neighbors, the near-Earth asteroids. Some of these objects pass closer to Earth than the Moon itself. They're leftovers from the inner solar system's formation some 4.6 billion years ago — keys to understanding the chemical mix from which Earth and its neighbors formed.

Asteroid compositions run the gamut from carbon-rich fragile structures, to fractured silicate rock, and slabs of solid iron. To deflect some future rock on an Earth-threatening trajectory, it's important that planetary scientists know what near-Earth asteroids are made of.

RUBBLE-STREWN asteroid Itokawa shows no obvious impact craters. Apart from a few smooth, dust-covered areas like Muses Sea, the asteroid's surface appears covered with boulders and giant rock fragments. Small impacts likely shook loose surface material and filled in old craters. ALL IMAGES ISAS/JAXA



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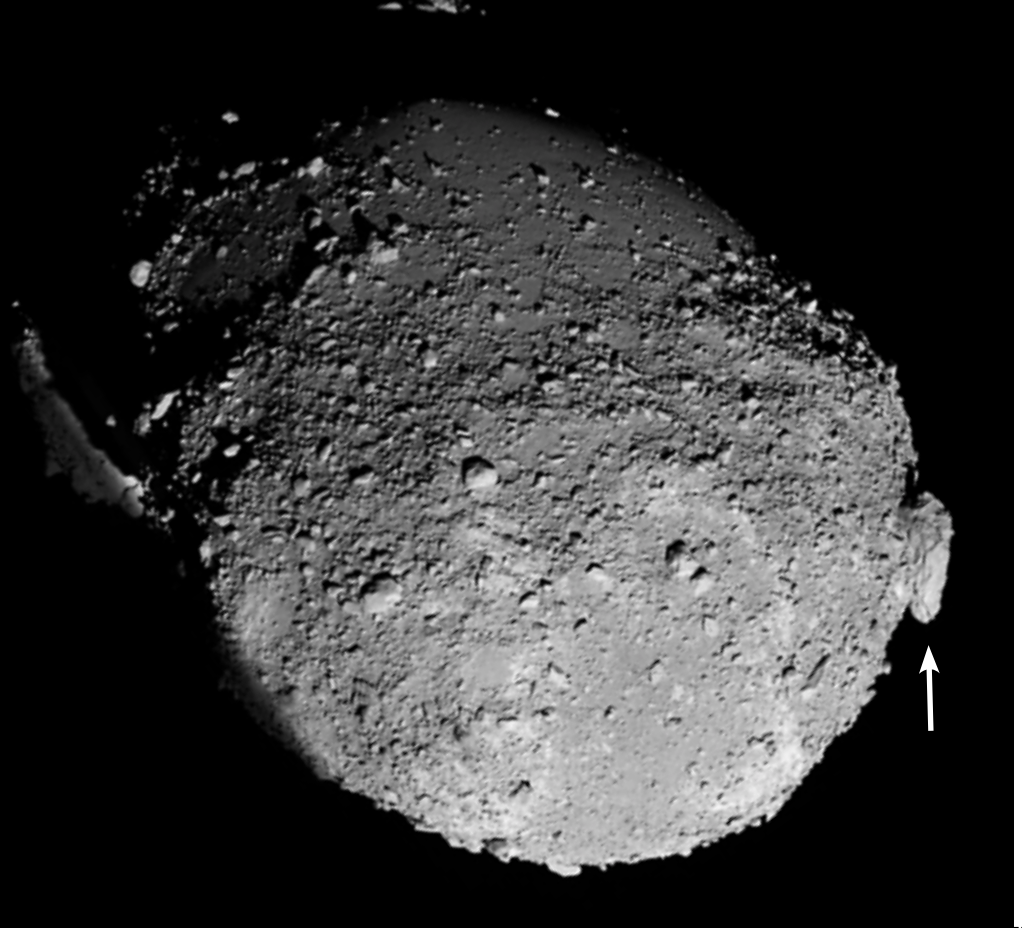
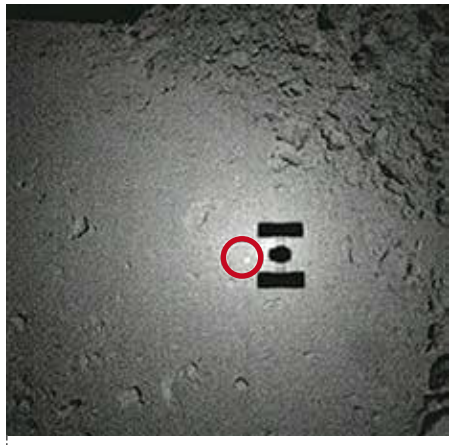




▲ HOVERING 105 feet (32m) above Itokawa November 20, 2005, Hayabusa imaged its own shadow. The bright spot (circled) is a reflective marker the craft dropped on the surface. The marker contains the names of 880,000 people.

◀ ITOKAWA seems to be a shattered body that re-agglomerated into a bizarre assemblage of rocky fragments. Note the giant boulder seemingly clinging to Itokawa's edge (arrow).

Although Hayabusa's potential science return is extraordinary, its main goal was to demonstrate new technologies. The first attempted round-trip to an asteroid flew with four novel, low-thrust, ion-drive engines. Onboard camera and guidance systems allowed Hayabusa to navigate its own approach to the asteroid's surface without help from controllers on Earth.

The probe's unique sample-collection device initially appeared to have worked well, but serious problems plagued the $170-million mission following its apparent success. Japan Aerospace Exploration Agency (JAXA) engineers now say the sampling attempt likely failed. The craft missed its scheduled departure date, and will continue flying in formation with Itokawa until at least spring 2007, when engineers hope to begin the probe's journey back to Earth.

Hayabusa's target, near-Earth asteroid (25143) Itokawa, is named for Japanese rocket pioneer Hideo Itokawa. It's one of the more accessible asteroids, with an orbit inclined only 1.7° to Earth's. Astronomers observed Itokawa in the optical, infrared, and with radar when it passed within 1.2 million miles (2 million kilometers) of Earth in June 2004. Radar revealed Itokawa is potato-shaped: 1,800 feet by 1,017 feet by 900 feet (550 meters by 310m by 275m). The asteroid's S-type spectrum indicates Itokawa's composition is related to meteorites known as ordinary chondrites. These are relatively common, iron-poor objects largely made of silicate rock.

Don Yeomans *is the U.S. project scientist for Hayabusa and a senior research scientist at the Jet Propulsion Laboratory in Pasadena, California.*

Hang time

In early September 2005, Hayabusa arrived at the asteroid. But it wasn't in orbit around Itokawa — the spacecraft was flying alongside as they both orbited the Sun. The asteroid's surface gravity is more than 100,000 times weaker than Earth's, and it has an escape velocity of only 0.3 mph (0.5 km/h) — ⅒ the speed of a brisk walk. An object that would freefall to the ground in half a second on Earth would fall for nearly 3 minutes on Itokawa.

Such weak surface gravity makes staying on the asteroid long enough to collect a sample problematic. So, Hayabusa's designers developed a touch-and-go technique that made Itokawa's low gravity work for, rather than against, the spacecraft. Essentially, Hayabusa docked with, rather than landed on, the asteroid.

Between September and December, Hayabusa investigated minerals on Itokawa's surface and mapped its rough surface features using cameras, near-infrared and X-ray spectrometers, and a laser altimeter. Hayabusa's images reveal Itokawa is an asteroid like none seen so far.

Most of its surface is covered with rocky boulders and giant rock splinters — there's not an obvious impact crater in sight. Scientists believe Itokawa is a "rubble-pile" asteroid — a loose collection of fractured rock and dust. Hayabusa's science team informally named one smooth, dusty region Muses Sea, a nod to the craft's earlier designation (MUSES-C). This would be the probe's landing site.

Rocky road

Hayabusa has experienced more than its share of setbacks since its May 9, 2003, blastoff from Japan's Kagoshima launch complex. In October and November 2003, it rode out some of the most intense solar flares on record. In late July 2005, one of the probe's three reaction wheels — devices that help the spacecraft maintain a given orientation — stopped working. Hayabusa lost a second wheel 2 months later. The craft relied on chemical thrusters, making a difficult task even more challenging.

Radio signals from Earth took 16 minutes to reach the probe at the asteroid's 180-million-mile (290 million kilometers) range, so Hayabusa had to guide itself to the surface. On November 4 and 9, the craft successfully rehearsed descents to Itokawa, coming within 230 feet (70m) of Muses Sea.

On November 12, the craft descended again to deploy a rover named MINERVA, which was to land on the asteroid, hop from one location to another, and send temperature measurements and images to its mothership. But orienting Hayabusa using its small thrusters required that commands from Earth supplement the spacecraft's autonomous system. This unusual situation led to the release of MINERVA at a time when Hayabusa was slowly drifting away from, rather than toward, the asteroid. The rover now orbits the Sun.

On November 19, controllers attempted a sample-collection run, but communication problems led them to believe Hayabusa had aborted its descent. Later analysis showed it had indeed touched the surface. It bounced twice, then settled onto Itokawa for 30 minutes before a command from Earth told it to ascend. Unfortunately, the craft had not been placed in sampling mode at the time.

On its descent, the probe released a target marker, which successfully landed on Muses Sea and reflected light from a flashlight-like device on the spacecraft. The marker gave Hayabusa an easy-to-spot reference for estimating its lateral speed near the surface. It also contains the names of 880,000 space enthusiasts from 149 countries who submitted their names over the Internet.

Shoot the asteroid

Mission controllers quickly prepared for another run. On November 25, at 7:35 A.M. Japan Standard Time, the spacecraft's sampling horn touched Itokawa's surface.

What happened next is unclear at this writing. Sensors detecting the touchdown were supposed to send a signal to the sampler, which was to fire two small gunpowder charges 0.2 second apart. These explosions would shoot two 0.18-ounce (5 gram) pellets of tantalum into the asteroid's surface. Tantalum is a rare metal that resists chemical change; scientists can easily identify any tantalum found in a sample.

The pellets would have struck Itokawa at 670 mph (1,100 km/h). Scientists expected about 1 percent of the dust ejected by these impacts would rise to the top of the sampling horn and enter a collection cell.

Less than 1 second after touchdown, Hayabusa fired its thrusters and lifted back into space. At first, everything appeared to have gone as planned. But JAXA engineers had little time to celebrate. Their craft began shaking and briefly lost contact with Earth. Fuel leaking from one set of thrusters probably caused the shaking, which ceased when controllers closed a valve, but fuel in a second set of thrusters appeared to be frozen. The craft may have cooled too much when leaked fuel vaporized.

Attitude problems forced solar-powered Hayabusa to run off its battery for too long, which may have led to a reset of the electrical system and loss of some data. Through early December, controllers struggled to get answers and resolve the craft's problems — a task made more difficult by Hayabusa's unstable orientation. Controllers could talk to the probe at only 256 bits per second through its medium-gain antenna.

On December 8, an "outgassing event" — probably vaporizing fuel — knocked the spacecraft out of alignment with Earth, ending all communication. The limited data controllers received seemed to indicate the spacecraft's sampler never fired its tantalum bullets, although it's remotely possible some of the dust stirred up during touchdown found its way into the collection cells.

A relatively small group of Japanese scientists and engineers has worked tirelessly to overcome Hayabusa's hurdles. This is a difficult, complex mission, and, like all great exploration efforts, it's right on the edge of what is possible and what is not.

Whether or not Hayabusa returns to Earth, planetary scientists value the rich set of data it has delivered already. By far the smallest asteroid to be investigated by spacecraft imaging, Itokawa may have been gently broken apart by tidal forces during a close approach to Earth or Mars. Or perhaps an impact with another asteroid caused a more violent breakup.

If controllers can get Hayabusa on its way in 2007, the probe is scheduled to return to Earth in 2010. Anxious planetary scientists will be waiting for its possible sample to land in the Australian outback. ▲

ONLINE EXTRA For more on Hayabusa's instruments and science results, visit www.astronomy.com/toc.

An object that would freefall to the ground in half a second on Earth would fall for nearly 3 minutes on Itokawa.

REFRIGERATOR-SIZE Hayabusa shows off its sampling horn (arrow) during assembly. Because the apparatus uses a small gunpowder charge to fire its pellets into the asteroid's surface, it was shipped to the launch site separately from the rest of the spacecraft.

HAYABUSA'S SCIENCE team poses beneath a full-size model of the spacecraft. The team includes some U.S. and Australian scientists.

Sungrazing comets

For comets straying too close to the Sun, breaking up is easy to do. Fragments may vaporize on their next pass or survive to create spectacular repeat displays. /// BY ZDENEK SEKANINA

Tally up the brightest comets on record — the ones astronomers consider Great Comets — and you'll find that a few of them passed less than a million miles from the Sun. A careful analysis of their orbits reveals other striking similarities. These are the "sungrazers," comets that race from the outer solar system's frigid darkness to kiss the Sun. Strong tidal forces may crack a sungrazer's icy nucleus, which then boils off so much gas and dust as it rounds the Sun that the comet may be visible from Earth during daylight.

Such events don't happen often. The last comet this scenario describes was Ikeya-Seki (C/1965 S1), which was discovered in 1965 by two Japanese amateurs, Kaoru Ikeya and Tsutomu Seki. On October 21 of that year, the comet swept 470,000 miles (760,000 kilometers) from the Sun's visible surface. The comet's Sun-skimming journey cracked its nucleus into at least two pieces.

Smaller sungrazers, though, are quite common. Satellites have discovered more than 1,000 mini-comets, some just a few yards wide, flaring as they plunge toward the Sun. None of these fragments survives its fiery passage.

Many travel on orbits strikingly similar to Ikeya-Seki and other famous sungrazers. Astronomers have good reason to believe both mini-comets and the bright sungrazers have more in common than a passing orbital resemblance. In fact, it's likely they are all fragments of a giant cometary granddaddy that broke up some 1,700 years ago.

Family ties

Two spectacular sungrazers appeared in the 19th century: C/1843 D1, also called

THE LAST BRILLIANT sungrazer was Ikeya-Seki, which broke apart just before it passed within 735,000 miles (1.18 million kilometers) of the Sun's surface October 21, 1965. Observers could see it during the daytime just by covering the Sun with a hand. *ASTRONOMY:* ROEN KELLY

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

LIKE A GHOSTLY SCIMITAR, **Ikeya-Seki rose tail-first into the morning sky a week after perihelion. The comet's twisted, rope-like tail reached 30° in length.**

the Great March Comet, and C/1882 R1 (the Great September Comet). Like Ikeya-Seki, both of these icy visitors could be seen during daylight when they were closest to the Sun. The Great September Comet of 1882 — the brightest sungrazer ever recorded — split into at least five pieces after it made its way around the Sun.

German astronomer Heinrich Kreutz (1854–1907) was intrigued by these appearances, and, in 1891, systematically investigated sungrazers' motions. He concluded the comets of 1843 and 1882 — as well as at least two others — traveled in similar orbits. Kreutz thought they might be pieces of a larger predecessor that broke apart after passing the Sun. This family of sungrazing comets is called the Kreutz group in recognition of the astronomer's work.

Kreutz also found the orbital period of the 1882 comet was about 770 years. Chronicles record a daylight comet in 1106 (see "A frightful sight" on page 39). Could these objects be one and the same? Kreutz certainly thought so.

Fast-forward 75 years.

Following the appearance of Comet Ikeya-Seki, and the addition of a few other members to the sungrazer club, astronomers recognized Kreutz's suggestion as correct but incomplete. In 1966, Ichiro Hasegawa of Japan and Czech astronomer Lubor Kresák independently recognized two distinct groups in the Kreutz comet family. The next year, American astronomer Brian Marsden at the Smithsonian Astrophysical Observatory in Massachusetts published a detailed analysis of both groups' orbits.

Subgroup I sungrazers, which includes C/1843 D1, passed slightly closer to the Sun than Subgroup II, whose members include C/1882 R1 and Ikeya-Seki. Marsden validated Kreutz's hunch by showing that the

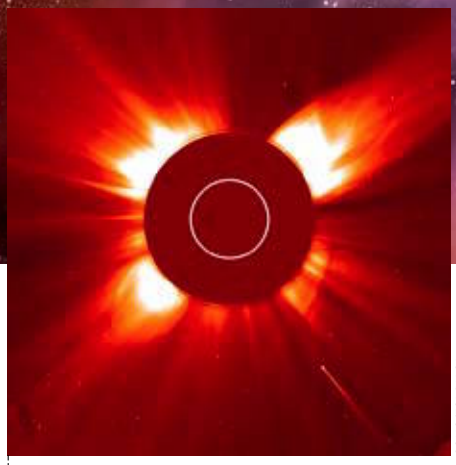
ALLPORT LIBRARY AND MUSEUM OF FINE ARTS, STATE LIBRARY OF TASMANIA

THE GREAT COMET **of 1843 streaks above the Tasmanian landscape. It was the first of two daytime sungrazers 39 years apart.**

Great September Comet and Ikeya-Seki both were likely fragments of the brilliant sungrazer seen in 1106.

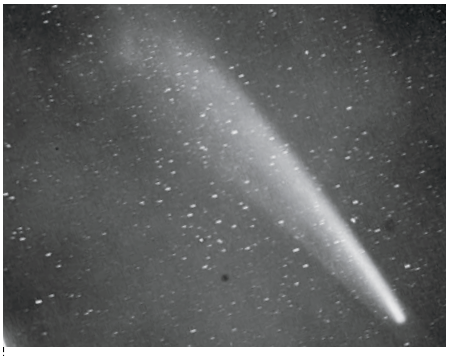
At the time of these studies, astronomers had just a handful of well-established sungrazer orbits to work from. That changed in August 1979, when an experiment called SOLWIND on a U.S. Air Force test satellite named P78-1 discovered a comet that dove toward the Sun — and then disappeared, apparently destroyed. SOLWIND was designed to study the Sun's tenuous outer atmosphere, or corona, by using an opaque disk to block out bright light from the Sun's surface. This type of instrument is called a coronagraph.

Since 1995, thanks to similar devices on the Solar and Heliospheric Observatory (SOHO), astronomers have cataloged more than 1,060 sungrazers. Nearly 900 of these objects are members of the Kreutz family. None of these mini-comets could be seen through ground-based telescopes. More



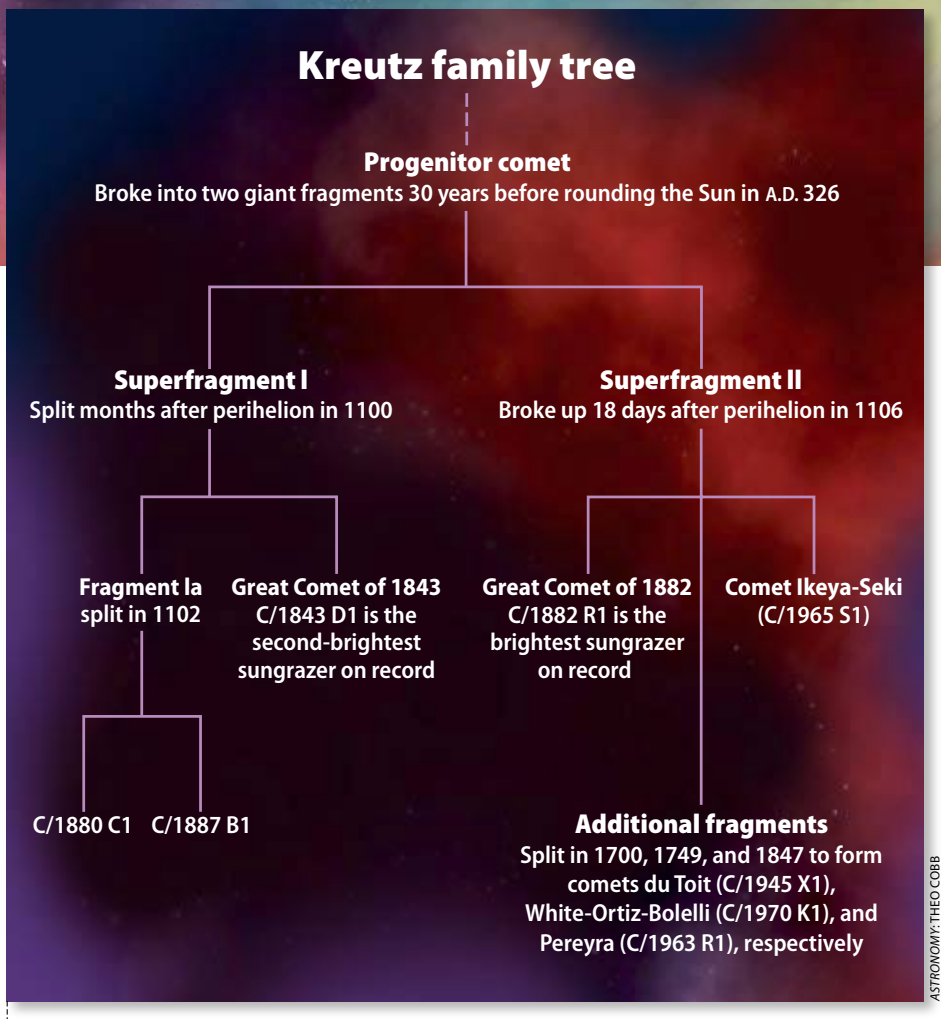
SOHO/ESA/NASA

SOHO CAPTURED Comet C/2001 U9's dive into the Sun October 23, 2001. The comet's tail glows brightly as intense solar radiation heats its frozen nucleus and increases its release of gas and dust.



SOUTH AFRICAN ASTRONOMICAL OBSERVATORY

ASTRONOMERS DISCOVERED the Great September Comet (C/1882 R1) on its way to the Sun. It was easily visible in broad daylight for more than 2 days near its September 17 closest approach to the Sun. Within 2 weeks, astronomers recognized the comet's icy nucleus had shattered.


Kreutz family tree
Progenitor comet
Broke into two giant fragments 30 years before rounding the Sun in A.D. 326
Superfragment I
Split months after perihelion in 1100
Superfragment II
Broke up 18 days after perihelion in 1106
Fragment Ia split in 1102
Great Comet of 1843 C/1843 D1 is the second-brightest sungrazer on record
Great Comet of 1882 C/1882 R1 is the brightest sungrazer on record
Comet Ikeya-Seki (C/1965 S1)
C/1880 C1
C/1887 B1
Additional fragments
Split in 1700, 1749, and 1847 to form comets du Toit (C/1945 X1), White-Ortiz-Bolelli (C/1970 K1), and Pereyra (C/1963 R1), respectively

ASTRONOMY: THEO COBB

THE KREUTZ FAMILY likely got its start in A.D. 326, when a giant comet split into two large pieces. This began a cascade of fragmentation that produced the Kreutz comets.

significantly, none has ever been detected after reaching its closest point to the Sun (perihelion). This last observation is critical for understanding how the Kreutz sungrazers age.

Separation anxiety

Comets move fastest when they're closest to the Sun. When a fragment breaks from an icy nucleus at perihelion, it slows down or speeds up by a small amount relative to the main nucleus. But because the comet is moving so fast, even a small change can alter the fragment's orbital period so much that it may come to perihelion hundreds of years before or after its parent does.

A peculiar attribute of SOHO sungrazers is their tendency to appear in pairs or clusters. These fragments often arrive at perihelion within hours of one another, and they follow similar but not identical paths. This clumping cannot be explained by breakups at perihelion, which would result in identical orbits. Something else must be going on.

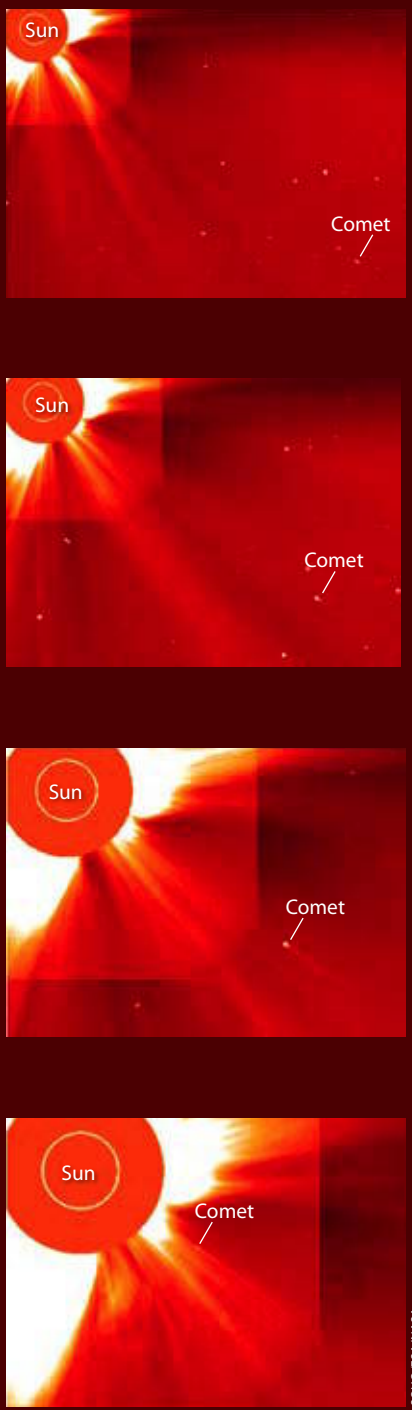
As part of my own research into sungrazers, I showed in 2000 that the clustering of sungrazers moving in slightly different orbits tells us the fragments are themselves fragmenting, and they're doing so near their farthest point from the Sun (aphelion). Calculations for close SOHO pairs show the fragments' separation velocities are typically just a few miles per hour. Rapidly rotating fragments appear to be flinging off pieces.

A FRIGHTFUL SIGHT

On February 7, 1106, shortly after the Sun set in Palestine, people looked to the sky with concern. A huge comet, its bright, narrow tail spanning more than half the sky, stood above the southwestern horizon. The comet was seen near the Sun in broad daylight in the first days of February, and reports say it remained visible until mid-March.

Mentioned in several Asian and European chronicles, this comet may have been the most widely observed during the 12th century. Studies of sungrazer fragmentation by astronomer Paul Chodas and myself show the comet of 1106 gave birth to Ikeya-Seki, the Great September Comet, and three other sungrazing comets. — *Z. S.*

Zdenek Sekanina *is a senior research scientist at the Jet Propulsion Laboratory in Pasadena, California.*



SOHO/ESA/NASA

THIS SEQUENCE OF SOHO images shows C/2002 S2 on its final plunge into the Sun. The images span September 17 (top) to 19, 2002. Sunlight boils water off the comet's surface, breaking ice molecules into their component ions. Bright sungrazers may lose as much as 220 pounds (100 kilograms) of ice each second.

DAYTIME SUNGRAZERS

Name	Closest to Sun	Minimum distance (AU)	Brightest magnitude
1106 (X/1106 C1)	Jan. 26, 1106	—	—
Great March Comet (C/1843 D1)	Feb. 27, 1843	0.0055	—
Great September Comet (C/1882 R1)	Sept. 17, 1882	0.0077	About –15
Ikeya-Seki (C/1965 S1)	Oct. 21, 1965	0.0078	–10

Imagine a sungrazer traveling on an orbit that takes it half a million miles (835,000 kilometers) from the Sun's center to about 200 times Earth's distance from the Sun (18.6 billion miles [30 billion km]). At perihelion, this comet sprints about 1.3 million mph (783,000 km/h). But at the other end of its orbit, at aphelion, it's moving just 36 mph (22 km/h). A fragment separating from its parent nucleus at just a few miles per hour near aphelion will see a significant change in its perihelion distance, and its orbit's angular elements can alter by many degrees.

The fact that none of the SOHO sungrazers survives perihelion confirms they must break up far from the Sun. SOHO sungrazers range in size from 30 to 650 feet (10 to 200 meters) across. These objects disintegrate when they pass close to the Sun, so they cannot have existed as separate objects for even a single previous orbital revolution. The fragments could have survived only as part of their parent body, which was large enough to survive a close approach to the Sun.

Comets like Ikeya-Seki show that sungrazers with nuclei several miles across can survive. Computer models indicate a fragment must be at least 0.6 mile (1 km) wide to make more than one pass around the Sun; the exact size depends on how close it approaches. None of the SOHO sungrazers is this large, so none of them survives. But if these fragments are distributed more or less evenly, they must number at least 200,000 to explain the present flux of SOHO sungrazers.

Similar comets

The behavior of C/1882 R1 bore a striking resemblance to Shoemaker-Levy 9, which approached within 1 planetary radius of Jupiter in July 1992 and broke into more than 20 fragments. These pieces then collided with Jupiter 2 years later. Astronomers often described Shoemaker-Levy 9, which was discovered after it split up, as a "string of pearls."

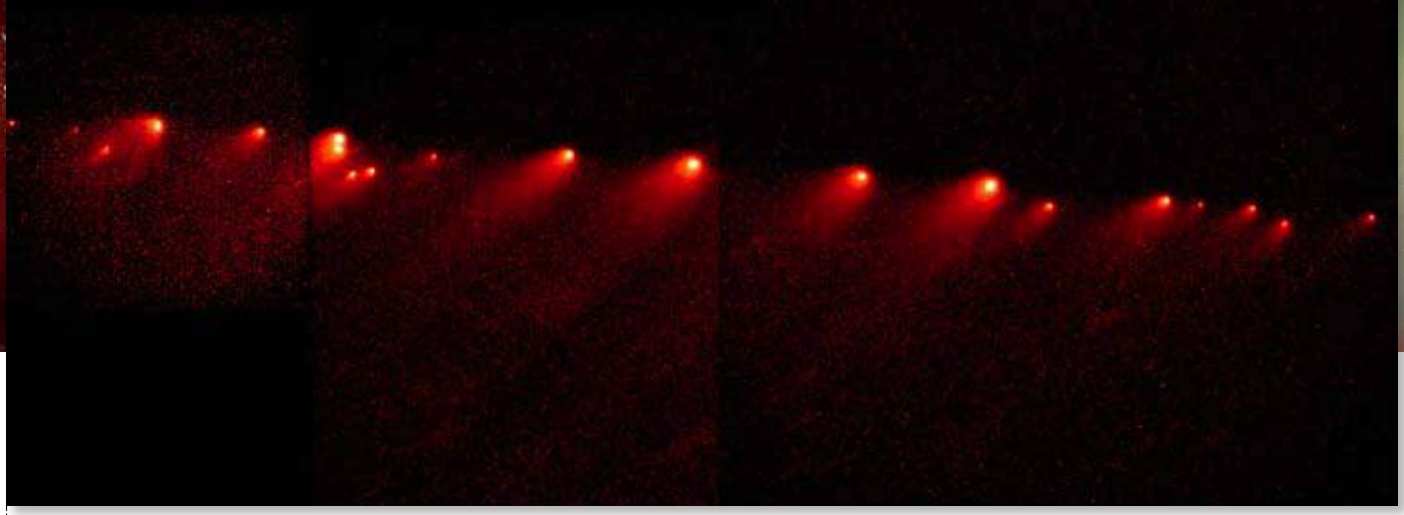
Likewise, the Great September Comet of 1882 broke into at least five separate nuclei after perihelion. Its fragments were also distributed in a line and sheathed in a common nebulous envelope. About 1 month after perihelion, in mid-October 1882, British astronomer David Gill described the nucleus condensation "as a narrow line ... with five little nuclei ... looking like very small beads strung on a thread of worsted." Similarly, at the end of January 1883, American astronomer Andrew Common described the five nuclei as appearing "like pearls on a string."

Observations reveal C/1882 R1 broke up about 2 hours after perihelion. Shoemaker-Levy 9 disintegrated about 3 hours after its closest approach to Jupiter. Working with Paul Chodas and Donald Yeomans, two

DID EPHORUS SEE THE FIRST BREAKUP?

In 372 B.C., the Greek historian Ephorus of Cyme reported seeing a bright comet split in two. Since Kreutz's time, astronomers have speculated that Ephorus may have seen the event that started the Kreutz comet family.

Trouble is, Asian chronicles of the time make no mention of the comet. Moreover, simply integrating C/1882 R1 back in time results in a perihelion around 315 B.C. This 57-year discrepancy makes it unlikely Ephorus witnessed the Kreutz group's founding. — *Z. S.*



H. WEAVER (JHU), T. SMITH (STScI), NASA

COMET SHOEMAKER-LEVY 9 was torn apart by Jupiter's gravity. Some of the fragments later broke apart on their own, paralleling the destruction of sungrazers. In July 1994, the Hubble Space Telescope imaged the pieces as a "string of pearls."

other astronomers at the Jet Propulsion Laboratory in Pasadena, California, I found that at least 13 of the 25 Shoemaker-Levy 9 fragments were products of secondary fragmentation events. That is, they weren't created by Jupiter's tidal effects on the comet's nucleus. As with Kreutz group comets, the behavior of Shoemaker-Levy 9 contradicts the conventional view that breakups occur only due to tides from a planet or the Sun.

Last gasp

C/1882 R1 was the brightest sungrazer on record, perhaps shining near magnitude –15 at its brightest. I estimate its mass at about 10 trillion tons — at least 10 times the mass of the population producing SOHO's sungrazers. With such a large fraction of its total mass locked in one fragment, the Kreutz group is obviously young. My studies suggest it may be just 1,700 years old.

Here's how I think the Kreutz group story fits together. A single massive progenitor comet perhaps 56 miles (90 km) wide sped toward the Sun. Stress from rotation, and the daily cycle of heating and cooling, cracked the giant nucleus while it was still farther than Pluto. In 326, the inbound comet split into two enormous fragments some 30 years before it would have reached perihelion.

The two superfragments continued their journey, gradually separating from each other on the way. When they returned to the Sun in 356, the fragments reached perihelion less than 1 week apart.

One orbit later, in 1100, Superfragment I reached the Sun nearly 6 years before the other. This time, the comet split apart several months after passing the Sun. The event produced two pieces, one of which returned as C/1843 D1. The other piece split again — probably in late 1102 — creating comets C/1880 C1 and C/1887 B1.

Superfragment II had an even more dramatic end. It returned in 1106 as the brilliant comet seen during the 12th century. About 18 days after it rounded the Sun, the comet split into five pieces. One pair became C/1882 R1 (the Great September Comet) and Ikeya-Seki. Breakups among the other fragments produced the three remaining sungrazing comets astronomers discovered between 1945 and 1970.

As the Kreutz comets split, their orbits become populated by more pieces of smaller size. How long can the system last? Using C/1882 R1's estimated mass, I find the system's life span is more than 10,000 years. So, a dozen orbits after the original Kreutz sungrazer broke apart, the last of its "children" will finally evaporate.

We are finally beginning to understand what these kamikaze comets are telling us. When will the next daytime sungrazer arrive? Astronomers can't say when, of course, but the record shows clearly it's only a matter of time. ■

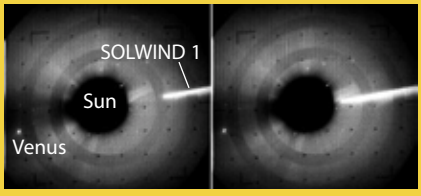
ONLINE EXTRA For more on SOHO's comet finds, visit www.astronomy.com/toc.

SOLAR SENTINELS

The Solar and Heliospheric Observatory (SOHO) was designed to study the Sun's structure and dynamics, its extensive outer atmosphere, and the origin of the ionized gas that flows from it (the solar wind). SOHO orbits around a location in space called the L1 Lagrangian point, about 930,000 miles (1.5 million kilometers) sunward from Earth. This position gives the satellite's instruments an uninterrupted view of the Sun.

SOHO, a cooperative effort between NASA and the European Space Agency, left Earth December 2, 1995, and was designed to last 2 years. By March 2007, when its current mission extension ends, SOHO will have monitored the Sun through a complete 11-year activity cycle.

In 1996, as soon as the spacecraft began sending back a stream of data, SOHO began its unintended role as history's greatest comet-hunter. Between 1979 and 1989, the U.S. Air Force Space Test Program P78-1 and NASA's Solar Maximum Mission satellites had discovered 20 sungrazers. SOHO bested them in its first year. Now, with more than 1,060 comet discoveries to its credit, SOHO is responsible for finding nearly half of all comets whose orbital parameters are known. Many of those reporting the discoveries have been amateurs studying SOHO images made available on the Internet (see ares.nrl.navy.mil/sungrazer). — *Francis Reddy*



NAVAL RESEARCH LABORATORY

SOLWIND 1, discovered in August 1979, was the first comet found by a satellite.

When the Mars rovers landed, mission scientists existed in martian time.

Forty extra minutes a day will throw anyone off schedule.

Living on MARS time

/// BY TIM PALUCKA

Universal Time
Nov. 8, 2005
23h00m00s UT

Jet Propulsion Laboratory
Pasadena, California
Nov. 8, 2005
15:00:00 PST

Spirit landing site
Gusev Crater, Mars
Sol 658
7:42:07

Opportunity landing site
Meridiani Planum, Mars
Sol 637
19:40:58

An old saying goes that a man with one watch always knows the time, but a man with two is never sure. When the Mars rover Spirit landed safely in Gusev Crater Saturday, January 3, 2004, Jeff Moersch, a member of the Mars Exploration Rovers (MER) science team from the University of Tennessee, looked at the watch on his left wrist. The time was 8:35 P.M. Pacific Standard Time. He then looked at the control-room display clock: It read 2:25.

But he did not adjust his watch to be synchronous; there was nothing wrong with it. Moersch's watch was tuned to Earth time, the display clock to Mars time.

One Mars solar day (or sol) is 39 minutes, 35.2 seconds longer than an Earth day. With a solar-powered rover on the Red Planet waiting for daily instructions from the science team, Mars time was more important than Earth time. Moersch and his colleagues would live by the display clock — on Mars time — for the anticipated duration of the project: 90 sols, or just over 3 Earth months.

Worse than jet lag

For the time being, though, they were living on pure adrenaline. Spirit's successful landing and the quickly available images of the martian surface made this the best landing Moersch had ever been involved with. "I've never seen one as smooth as this," he said. "It exceeded expectations in so many ways."

Hundreds of team members were on hand for the landing, and many stayed up 48 hours straight in excitement. The name they gave to a nearby crater — Sleepy Hollow — was based on their fatigue.

Once the rush wore off, mission scientists settled into a wake/sleep routine unlike any they had experienced before. The nominal 40-minute difference between Earth and Mars time constantly advances, so scientists had to go to sleep 40 minutes later every day instead of maintaining a constant bedtime. If you normally go to sleep at 11:00, try waiting until 11:40 tomorrow, 12:20 the next day, and 1:00 the day after that; see what this does to your wake-up schedule.

"You have to constantly force yourself to go back to sleep," Moersch said. "With only a 40-minute difference, your body has already had most of its sleep; it's hard to go back for another 40 minutes." Under the supervision of NASA sleep experts, the scientists practiced living on Mars time in a series of 1-week sessions during the 6 months prior to the rover landings.

What's the point?

To maximize Spirit's solar-power reserves, MER scientists have to send commands to the rover by Mars' sunrise. Moersch and his colleagues' main duty was to figure out what those commands should be. "The plan is to send one set of commands to the rover at the beginning of every day," Moersch said. "So we have to stay in synch with the planet's rotation."

Based on what Spirit saw that day, as seen in the downloaded science data containing photographs and perhaps chemical spectra of the soil, scientists had 4 hours to decide how to proceed. Should Spirit stay in the same place and take more data or should it drive over to the interesting rock formation that appeared in one of the photographs? It is this 4-hour window between downloading data from the rover and uploading commands for the next day that forced Moersch and the other team members to follow a shifting schedule. They had to be wide-awake during that window.

NASA/JPL-CALTECH

ONE OF THE FIRST 3-D images from Spirit was shown in the control room January 15, 2004. Nagin Cox, Deputy Team Chief for the Spacecraft Rover Engineering Team at the time of the image, is wearing four watches: one on Earth time, one accelerometer, one set to Spirit, and one set to Opportunity.

CLOCKS TELLING THE TIME at the rover landing sites run on a 24-hour cycle. Mars' seconds are longer than Earth seconds to force the 39.5-minute per day difference between the two planets. The clocks show two locations on Earth and two on Mars. *ASTRONOMY*: ROEN KELLY; MARS PHOTO: STScI

The simple things in life

In the humorous science-fiction novel *The Hitchhiker's Guide to the Galaxy* by Douglas Adams, space travelers are cautioned to take a towel with them wherever they go. Moersch would suggest aluminum foil and duct tape are more valuable commodities.

NASA provided out-of-town science-team members — including Moersch — with apartments during the project, but sleeping on a constantly moving schedule presented challenges. The first

Moersch started to lose track of Earth time.
"That's good for me," he insisted. "It means
I'm attuned to the mission when I start
thinking on Mars time."

was making the room dark. A trip to the local grocery store to purchase thick aluminum foil and duct tape was all Moersch needed. "I pretty much turned my room into a dark vault," he said. To drown out street noise, he played a loop of a forest stream. He felt bad for those on the team who lived in their own homes during the mission. Imagine having your family adjust to the schedule.

Four days into the mission, Moersch started to lose track of Earth time. All meetings and duties were scheduled on Mars time, so he used the control-room display almost exclusively. "That's good for me," he insisted. "It means I'm attuned to the mission when I start thinking on Mars time." At this point, he was getting up in mid-afternoon and coming home at 3 in the morning.

When he started living on Mars time, he had 4 hours of free time after he woke up before he went to work; after a few days, he was mostly adjusted and, once he woke up, went straight to work and had 4 free hours after he came home. He noticed signs of fatigue in others, but not in himself.

In many ways, this experiment in living on Mars time was similar to what a shift worker on Earth experiences. Moersch had the same frustrations: finding a restaurant that serves dinner at 4 A.M. and finding something interesting on television in the middle of the night. "It's the simple things, like finding time to talk to my wife back in Tennessee," Moersch said. "I'm on Mars, and she's on Earth."

Tim Palucka *is a space journalist based in Pittsburgh.*

A MARTIAN SUNSET serves as a reminder of the passage of time and signals the end of Spirit's day. The rover took this image May 19, 2005, during its 489th sol, 399 past the mission's scheduled end. NASA/JPL/TEXAS A&M/CORNELL

Understanding sleep

Many team members wore two wrist devices — an Earth-time wristwatch and a Mars-time wristwatch — and some even had three. The third is not a timekeeping watch but an accelerometer incorporated into a wristwatch casing. This device tells sleep researchers when someone has stopped moving. This is a reliable way to determine when people fall asleep and wake up, according to Melissa Mallis, the principal investigator of the Fatigue Countermeasures group at NASA's Ames Research Center.

She says NASA Ames focuses mostly on aviation — pilots suffering from fatigue in transmeridian flights — and not on space travel. But when the MER team realized fatigue might become a performance and safety issue, it asked Mallis to talk with team members about the best ways to deal with fatigue.

She arranged sessions prior to the MER landings to educate team members and have them practice adjusting their sleep/wake schedules. Because Moersch would live on Mars time, he attended a few sessions. About 30 people volunteered to keep a journal and record their sleeping and waking times, along with how they felt during the day. Moersch, however, was not one of them.

"The MER team has an advantage because they are extending their day," Mallis explains. In trials where people are isolated from light/dark signals, the natural circadian biological system runs about 24.2 hours, so it is easier to extend your day than to shorten it, according to Mallis. If the rover scientists were actually on Mars and exposed to the martian light/dark cycle, they might adjust rapidly.

But living with Earth's light/dark cycle while on Mars time poses challenges. Because our circadian rhythms are mainly affected by light, Mallis suggests that workers coming home in daylight after a night shift wear sunglasses to signal their body that it is time to sleep; when they get up in darkness, they should expose their bodies to light to force themselves to wake up.

Perhaps the biggest challenge is learning to sleep during the Earth day. Besides making the room as dark as possible, Mallis also encourages "strategic napping." If you have trouble sleeping during your 8-hour sleep period — the recommended amount of sleep each night — take a long nap before going to work. Napping rooms were provided for team members who needed a refresher during their shifts. In this case, Mallis says the nap should be limited to 30 minutes to avoid going into a deep sleep. "If someone is awakened during deep sleep, their performance in an emergency situation may be impaired," she warns.

Adjusting to Mars

By January 30, four weeks into the project, Moersch was still going strong. In fact, the adrenaline was back. "We just put 12 wheels on the ground," he said, referring to the landing of six-wheeled Opportunity, Spirit's twin, at Meridiani Planum on the opposite side of Mars. "The engineers are resuscitated," he added. NASA has never had so many wheels on Mars at the same time, and the rovers, 2 years later, are still operating.

But all had not been rosy. In the first few weeks after touchdown, Spirit developed difficulties that the media began reporting as a mission failure. Moersch was on planned leave at the time, home at the University of Tennessee in Knoxville, and with his family. The transition to Tennessee was rough, according to Moersch. He worked all night and then caught a morning flight home; the combined experience was like "flying home from India," he said.

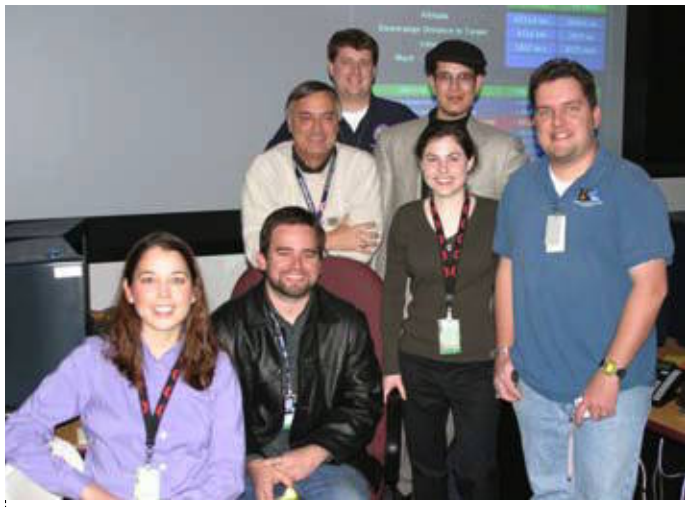
He received daily e-mails from mission managers about the problem, but he was never worried. "I had a pretty good feeling they would recover it," he said, referring to Spirit. "I've been on enough missions to realize there is usually a software problem somewhere along the way, but that's easier to fix than a hardware problem."

This time it was Spirit's onboard computer rebooting itself 60 times a day. The scientists "reinstalled the whole operating system of the computer from Earth," he said, to fix the glitch.

The original plan was to work 2 weeks at a time in California, followed by 1 week at home, but Moersch began to rethink that schedule. Spending every other weekend at home seemed to be the right cycle. "The hardest thing is not the time so much — it's not being able to be with my family," Moersch said.

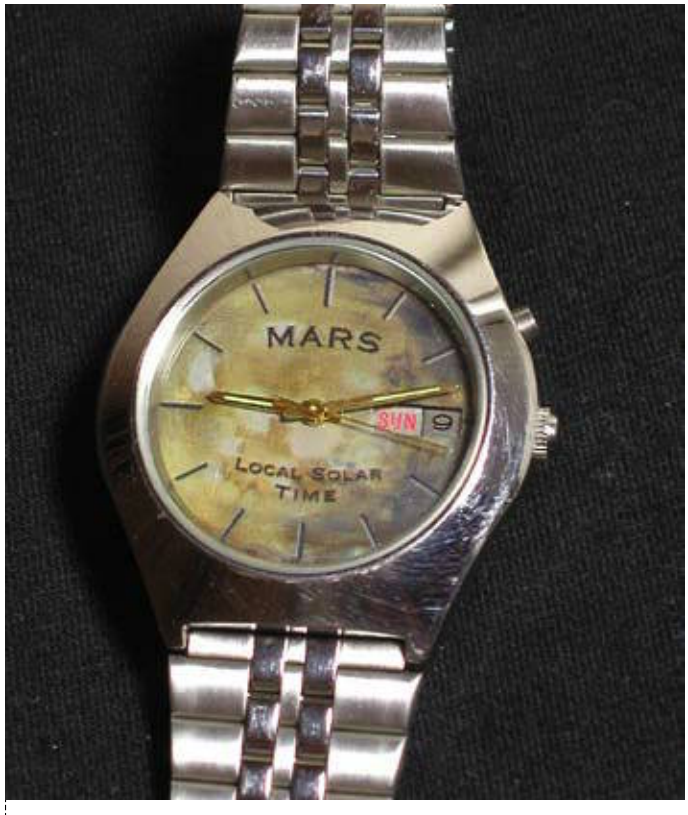
The thrill of being part of a great scientific adventure is a strong lure, and he found ways to stay on the project with Opportunity, the rover that landed January 24. He still spent most of his time working on Spirit, however, living on Mars time for the anticipated 90-day mission.

Two years later, the rovers have outlived all expectations, and mission scientists have since found ways to work with the rovers while scheduled on Earth time. During the 3-month experiment, team members worked productively on Mars time, proving that when humans do land on the Red Planet, they will adjust easily to their new time zone. A



JEFF MOERSCH

JEFF MOERSCH (in back) and the rest of the MER team from the University of Tennessee pose for a group photo. One of Moersch's students (front right) is wearing two watches: one Earth, one Mars.



NASA/JPL-CALTECH

THE MARS WATCH was an accessory on many team members' wrists. A local watchmaker modified normal watches by adding weight to their pendulums, forcing them to tick 39.5 Earth minutes per day slower. Some watches are on Spirit — or Gusev — time, while others are on Opportunity — or Meridiani — time.

ONLINE EXTRA Read about the first mechanical "Mars time" watch and how it was made at www.astronomy.com/toc.

WARNING

Dust Ahead

The biggest hitch for NASA's plans for human visits to the Moon and Mars may be one thing both worlds have in common — dust.

/// BY TRUDY E. BELL

Dust may be one of the greatest challenges facing astronauts exploring the Moon and Mars. Scientists and astronauts say it sticks to spacesuits, wreaks havoc on equipment, and may be physically harmful.

I can relate. On an expedition to Akjoujt, Mauritania, I had the closest experience to living on the Moon or Mars as I likely ever will. I was in the western Sahara Desert with a group of 200 amateur astronomers to watch the June 30, 1973, total solar eclipse.

Trudy E. Bell *is the author of 10 books on science and on bicycling for both adults and children. She is also managing editor for the* Journal of the Antique Telescope Society.

The Sahara right after the summer solstice is not the place to be: The Sun blazes from the zenith and bakes the landscape at 135° Fahrenheit (57° Celsius). Yet, the worst of it wasn't the heat. It was the dust.

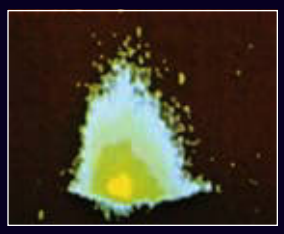
We were camped on stony plains. But incessant wind blasting the dry hardpan kept the air so full of silt-fine dust that the daytime sky was yellow instead of blue. Each afternoon, the Sun "set" into a brownish haze while still 10° above the horizon.

The dust was as abrasive as sandpaper. It infiltrated fabrics, telescope tubes and mounts, cameras, and film canisters. It collected at elbows and knees, and inside shirts and shoes, and gritted in teeth. Yet my experience is nothing compared to what may await future astronauts.

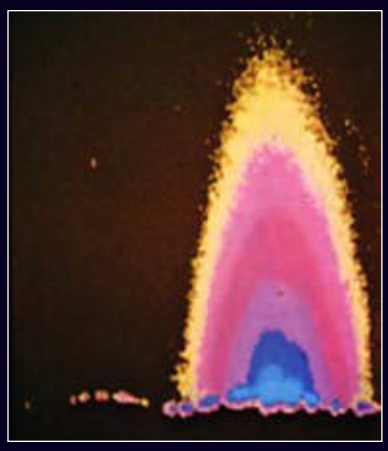
LUNAR TWILIGHT rays and glows, reflected in the astronaut's helmet above, occur because sunlight scatters off small dust particles above the Moon's surface. The light show may be cold comfort, for lunar dust is nasty stuff — tenacious, abrasive, and a health hazard if ingested. Below: Over billions of years, meteorite impacts have pummeled the Moon's surface into dust as fine as talcum powder. *ASTRONOMY:* JAY SMITH; NASA

Lunar twilight

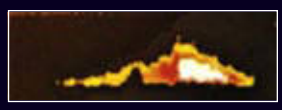
Surveyor 1
Oceanus Procellarum



Surveyor 5
Mare Tranquillitatus



Surveyor 6
Sinus Medii



Surveyor 7
Tycho's north rim

ON THE MOON'S SURFACE, robotic landers from the U.S. Surveyor program recorded twilight glows for an hour or more after sunset. These images, shown in false color, are the first frames with lunar twilight glows recorded by each of the missions that detected them. NASA, COURTESY DOUG CRISWELL

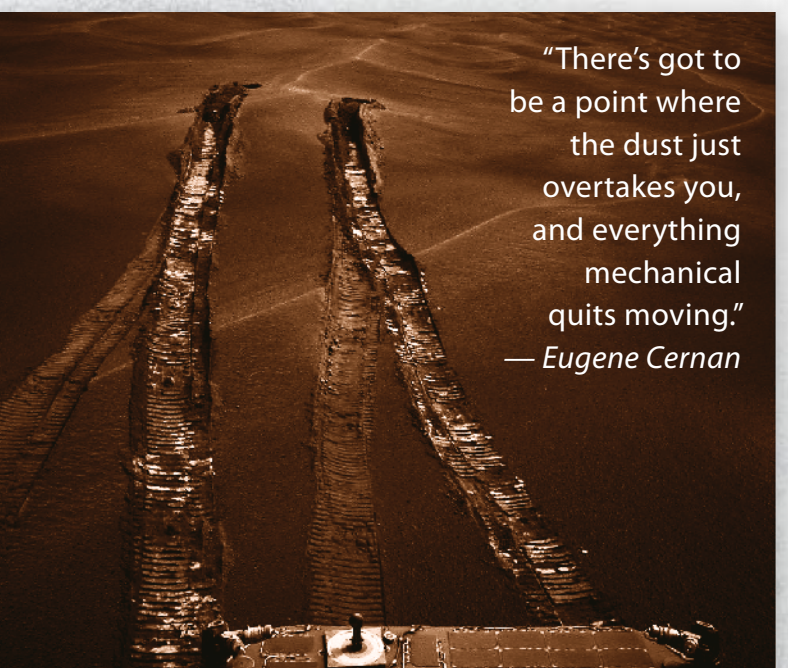
FROM ORBIT, Apollo 17 astronaut Eugene Cernan sketched bright glows and rays that appeared a few minutes before each lunar sunrise. Two minutes before sunrise (T–2), "streamers" became more prominent. Sunlight scattered off lunar dust particles caused the displays. NASA

Ranking risks

Since January 2004, when President George W. Bush articulated his Vision for Space Exploration in the 21st century, NASA has worked toward landing humans on the Moon by 2020 and Mars the decade following. NASA must return to the Moon, which will serve as a test bed for resource utilization techniques and human operations, before committing human lives to a Mars expedition. If mining and processing equipment can work efficiently and reliably on the Moon, scientists say it should also function well on the Red Planet.

In June 2005, the Mars Exploration Program Analysis Group (MEPAG), which NASA chartered to help plan martian exploration, concluded that an incomplete understanding of the planet's environment could result in a faulty design for a crewed Mars mission. Among MEPAG's top recommendations was a characterization of martian dust and its effects on both hardware and human health.

Mars is a dusty place. Ground-based telescopes have long revealed that, every few years, a dust storm engulfs the entire planet for months. The Mars Exploration Rover Spirit has returned images of dust devils swirling around Gusev Crater.



"There's got to be a point where the dust just overtakes you, and everything mechanical quits moving."
— Eugene Cernan

Half the planet away, rover Opportunity became bogged down for weeks at Purgatory Dune when its wheels sank into unusually fine material.

While we haven't yet obtained samples of martian dust, planetary experts have samples of lunar dust to examine, as well as the first-hand experiences of Moon-walking Apollo astronauts. Both worlds are covered with a fine, dusty layer of broken-down rock. This is a hazard that both Mars- and Moon-bound astronauts will face, but studying the lunar environment is more practical.

"It's a lot easier to send, retrieve, study, and repair hardware if the travel time each way is only 3 days instead of 6 months," says Philip Metzger, a physicist with NASA's Spaceport Engineering and Technology Directorate at Kennedy Space Center in Florida. The shortest Mars missions NASA is now considering would last 13 months: 1 year for the round trip, plus a month on the planet's surface. More ambitious scenarios call for longer stays. Astronauts would excavate martian soil to transform subsurface ice into potable water, breathable air, and even fuel for the trip home.

Abrasive, annoying, and harmful to your health

Moon dust is weird — even weirder than Apollo-era scientists fully appreciated. It's a fine, highly abrasive grit of rock and powdered

MARS EXPLORATION ROVER Opportunity reversed its course after encountering unusually soft sand at what controllers named Purgatory Dune. The craft's wheels dug in more than 4 inches (10 centimeters) April 26, 2005. After more than 5 weeks of planning, testing, and painstaking driving, rover controllers nudged Opportunity off Purgatory Dune and onto firmer soil. NASA/JPL

"Looks like you guys have been playing in a coal bin."
— Apollo 16 mission control

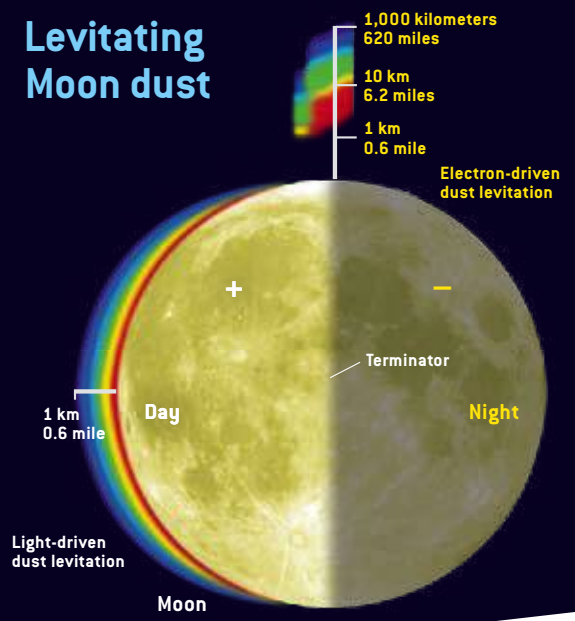
APOLLO 16 astronaut Charles Duke, Jr., collects rock samples near Plumb Crater on the Moon. Dark dust covers Duke's spacesuit. NASA

glass. As the dozen Apollo astronauts who trod on the Moon between 1969 and 1972 learned, brushing the dust off a spacesuit's sun visor scratches its protective layer of gold. Dust in spacesuit joints fouled attachment points and air seals. Dust clogged bolt holes and chewed through protective gloves.

Each of the motorized Lunar Rover vehicles astronauts used on Apollos 15, 16, and 17 broke a fender. This sent a rooster tail of dark dust raining down on vehicle's occupants and experiments. Apollo 17 astronaut Eugene Cernan declared, "There's got to be a point where the dust just overtakes you, and everything mechanical quits moving."

Lunar dust at the Apollo sites was as black as graphite, and it clung to everything. On the astronauts' visors, it restricted visibility like a dirty windshield. When they tried to brush off each other's spacesuits before reentering the Lunar Module, the particles dug deeper into the tight-woven fabric. White spacesuits turned a dingy gray — mission control for Apollo 16 once quipped, "Looks like you guys have been playing in a coal bin." Experiment surfaces that were once reflective began absorbing harsh solar radiation, which caused several scientific instruments to overheat.

Lunar dust is a biological irritant, too. The fine particles worked themselves so deeply into Cernan's fingernails, it took 3 months for the grit to grow out. Worse, the dust astronauts tracked inside the Lunar Module's single-room cabin eventually became airborne. Several crews reported eye irritation and an odor like spent gunpowder. The moment Apollo 17 moonwalker Harrison Schmitt inhaled some of the airborne dust, his nasal passages swelled shut. "I didn't know I had lunar-dust hay fever," he observed.



SMOKE-SIZE DUST particles 1 micrometer in size or smaller on the Moon's surface may become electrically charged. Sunlight can knock off electrons, leaving a net positive charge during the day; after the Sun goes down, solar-wind electrons strike the Moon, adding a negative charge.

Like charges repel one another, so, when enough charge accumulates, the particles launch themselves into space. How high they go depends on their size. Here, the location of the smallest dust particles is shown in violet; warmer colors indicate larger particles, up to 1 micrometer (red). *ASTRONOMY:* JAY SMITH

Dancing dust

Lunar dust also seems to be electrically charged. The U.S. Surveyor program's robotic landers touched down on the Moon years before Apollo astronauts did. Lander images taken after sunset, when only earthlight should illuminate the landscape, show persistent twilight glows above the horizon.

Astronauts aboard Apollos 8, 10, 15, and 17 repeatedly described and sketched phenomena they called "bands," "streamers," or "twilight rays" — anomalous glows seen minutes before each lunar sunrise or after lunar sunset. Their sketches of these glows resemble Earth's crepuscular rays — the beams of sunlight and shadow seemingly radiating up from the horizon as the Sun rises or sets behind low clouds. Crepuscular rays occur on Earth because water droplets and atmospheric dust at high altitudes scatter sunlight toward us.

In the 1970s, several planetary scientists speculated that both the Surveyor horizon glows and the twilight rays drawn by lunar astronauts had the same cause. Scientists suggested dust somehow suspended miles above the Moon was scattering sunlight. But how could lunar dust get up there, and why would it hover so high instead of falling back to the surface?

Last year, a team led by Timothy Stubbs of the Laboratory for Extraterrestrial Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland, offered an answer. The group suggests individual, microscopic grains of lunar dust continually leap up from the Moon's surface and fall back down. The scientists call this a "dynamic fountain model" because it evokes the image of a drinking fountain. "The arc of water coming out of the spout looks static, but we know the water molecules are constantly in motion," Stubbs says.

What drives ultrafine dust particles off the Moon's surface? Stubbs and his colleagues think it's static electricity.

On the Moon's sunlit side, energetic ultraviolet and X-ray photons kick electrons out of atoms and molecules in lunar soil. A similar thing happens during the 2 weeks of lunar night, they say, but from a different cause: the solar wind. These solar electrons flow around the Moon and strike its night side. A positive charge builds up all over the daytime lunar surface, and a negative charge builds up all over the Moon's nighttime surface. Like charges repel one another, so, once the surface charge becomes high enough, dust grains 1 micrometer and smaller launch themselves to heights ranging from several yards to even miles above the lunar surface. Although the grains fall back down, the process continues across the Moon. This creates, Stubbs explains, "a tenuous atmosphere of moving dust particles."

At the terminator — the moving line of sunrise or sunset between the Moon's day and night sides — sunlit soil, with its net positive charge, meets negatively charged night soil. Stubbs speculates strong horizontal electric fields might push dust sideways across the terminator. Apollo astronauts reported nothing like this, but the largest flows scientists envision would involve particles far too small to see.

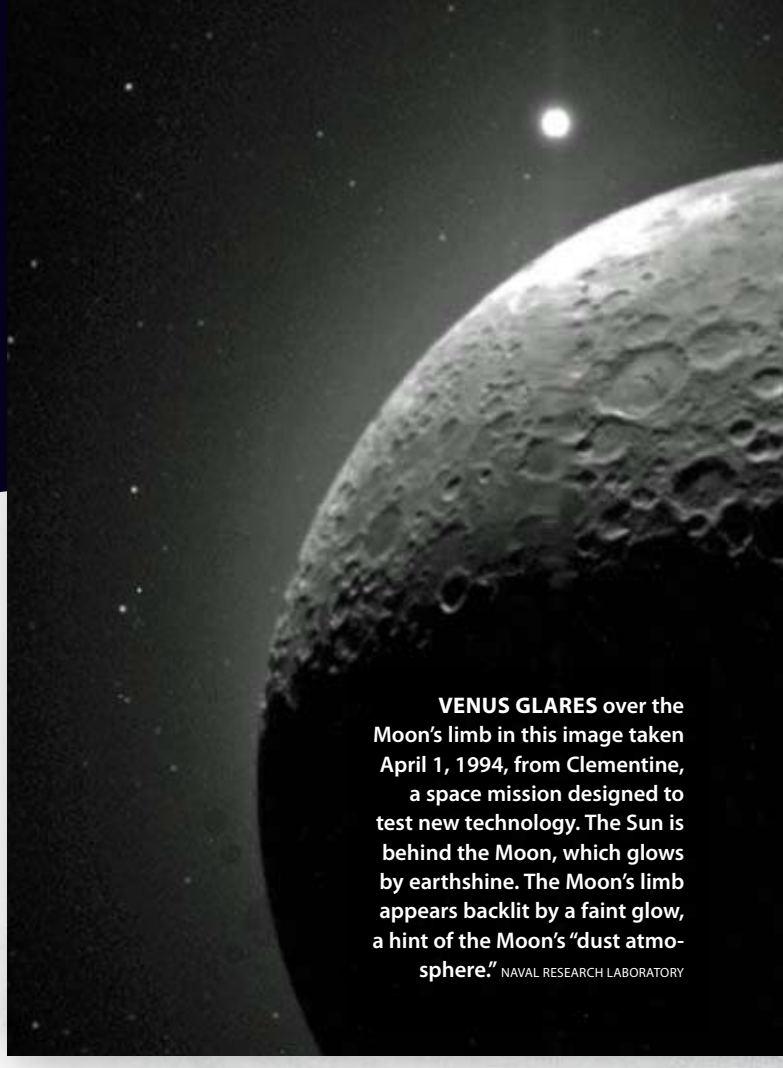
"Breathe in even micron-size specks, and you're a goner." — *Stein Sture*

Mars charge

On Mars, astronauts may face an entirely different electrical problem. Geoffrey Landis, a physicist at NASA's Glenn Research Center in Cleveland, says astronauts may accumulate a significant electrical charge just walking around on the surface. That could be bad

WHEN SCIENTISTS tested the Sojourner rover's wheel on simulated martian soil, it accumulated hundreds of volts of electrical charge. Scientists outfitted the microwave-oven-size rover with fine needles to bleed its charge into the atmosphere. Mars Pathfinder brought Sojourner to the martian surface July 4, 1997. NASA/JPL

THE MOON'S Langrenus Crater may have been a recent source of dust. In the 1990s, scientists reported bright glows near the 80-mile-wide (130 km) crater's central peak. They suspect gas held in pockets deep within the Moon suddenly vented, taking surface dust along. DAMIAN PEACH



VENUS GLARES over the Moon's limb in this image taken April 1, 1994, from Clementine, a space mission designed to test new technology. The Sun is behind the Moon, which glows by earthshine. The Moon's limb appears backlit by a faint glow, a hint of the Moon's "dust atmosphere." NAVAL RESEARCH LABORATORY

news for spacecraft electronics they encounter when they return.

Similar physics is responsible for shocking experiences with doorknobs here on Earth. Walking across a carpet on a dry winter day lets the human body accumulate up to 15,000 volts of negative charge. Reach for a conductor, like a doorknob, and all the accumulated electrons discharge at once in a painful spark.

Landis and his colleagues worried about this sort of charging before NASA launched Mars Pathfinder in 1996. "When we ran a prototype wheel of the Mars Pathfinder over simulated martian dust in a simulated martian atmosphere, we found it charged up to hundreds of volts," he recalls. The discovery so concerned scientists that they added ultrathin tungsten needles beneath the rover to bleed excess charge back into the martian atmosphere. The bigger the object, the more this electrostatic charging becomes an issue. So, both of the larger Mars rovers Spirit and Opportunity received the same type of protection.

Poisonous planets?

Lunar dust is composed mostly of silicon, like quartz, and while it isn't toxic, it's by no means safe. Russell Kerschmann, life sciences chief at NASA's Ames Research Center, Moffet Field, California, explains that Moon dust's fine, powdered-glass texture resembles "silicate dust on Earth that causes silicosis, a serious disease that has caused a lot of deaths" among miners.

Silicosis first came to widespread public attention during the Great Depression. More than 700 miners who inhaled quartz dust while drilling the Hawk's Nest Tunnel through Gauley Mountain, West Virginia, died within 5 years of exposure. It was one of the nation's biggest occupational-health disasters.

When quartz particles smaller than 1 micrometer reach the lungs, Kerschmann says, they can embed themselves in the tiny alveolar sacs, where cells exchange carbon-dioxide gas for oxygen. Once this deep, the dust can't be removed by coughing, and even the immune system is powerless. The sharp-edge particles cut up any white blood cells that try to engulf them. Blood proteins fill the lungs, and the victim slowly suffocates.

In addition to being a mechanical irritant, martian dust may also be toxic. Martian soil is red because it's composed of mineral oxides, including iron oxide (rust). Some scientists suspect the martian soil may be such a strong oxidizer, it will burn things like plastics, rubber, or human flesh as viciously as laundry bleach.

"Breathe in even micron-size specks, and you're a goner," declares Stein Sture, professor and associate dean in the College of Engineering and Applied Science at the University of Colorado in Boulder. Moreover, according to data from the Pathfinder mission, martian dust may also contain trace amounts of toxic metals, including arsenic and hexavalent chromium — the carcinogenic waste product made famous in the 2000 film *Erin Brockovich*.

Risk reduction

To find ways of mitigating the hazards of lunar and martian dust on robotic and human exploration, NASA began funding Project Dust in 2005. This is a 4-year study headed by Masami Nakagawa, associate professor in the mining engineering department of the Colorado School of Mines in Golden. Project Dust studies technologies like dust-repellant film coatings for lunar tools and methods for removing dust from spacesuits.

Meanwhile, Kerschmann hopes NASA will also consider funding a toxicology study of lunar and martian dust. Such a study would help answer some important questions. For example, how much dust can remain in water derived from subsurface ice without affecting astronauts' health?

"Do we need to remove every last particle, or just certain sizes of particles?" Kerschmann asks. "[The answer] will impact the design of spacesuits, airlocks, air purification systems, and habitats." He and many others also hope for a Mars sample-return mission before humans take the next big step for mankind.

ONLINE EXTRA NASA has produced simulated lunar soil for researchers. Learn how the agency did it at www.astronomy.com/toc.

MARCH 06

Bodies in the solar system are constantly on the move. A pair of eclipses just skims the surface of the many dynamic events visible this month.

Solar disappearing act

One of nature's grandest spectacles, a total eclipse of the Sun, greets observers in the Mediterranean region March 29. With all the fascinating things to watch — the corona, Baily's beads, shadow bands, and projected solar crescents — it's easy to miss the physiological effects on the body. The rapidly plunging light levels just before totality often trigger a weird mixture of excitement, panic, and foreboding. As soon as sunlight returns, unbridled elation and quiet personal reflection are normal. It's different for each person, and from one eclipse to another.

Compared with last April's oceanic totality, this eclipse crosses reasonably accessible land with mostly favorable weather conditions. If you can't make it to this eclipse, start planning for the long-lasting, nearly 7-minute total eclipse that will cross the Far East in July 2009. There are no total solar eclipses in 2007, and the only one in 2008 crosses the Arctic before heading south through Siberia into China.

A different event arrives the evening of March 14 this year, when the Moon passes into Earth's penumbral shadow. Observers from the Rockies eastward can catch the eclipse's end as the Moon rises shortly after sunset. Folks farther east get a longer view. At no time will a dark bite be taken from the lunar disk, but on close inspection, you should see a grayish shading. The normally bright highlands across the Moon's southern hemisphere will be dimmed, giving the whole disk a flat appearance.

BAILY'S BEADS highlight the final seconds before the Moon blocks the Sun's photosphere during a total solar eclipse. FRED ESPENAK

Most noticeably, the Moon will take on a yellowish tinge close to mideclipse, at 6:48 P.M. EST. When the rising Moon shines through the lower layers of our atmosphere, it's often painted a pale yellow to pink as a matter of course, but the penumbral shading should make this effect stronger.

Be sure to catch Mercury early this month, before it disappears from view. The solar system's fastest planet is easy to pick out of the twilight after sunset, low in the west. Don't wait, because it fades quickly in the last week of February, making a switch to binoculars necessary in early March. No bright stars lie nearby to confuse the planet's identity.

Saturn perches high in the southeast as twilight fades, and the view improves through late evening because you have less of Earth's atmosphere to peer through. The golden beacon lies off the western edge of the Beehive star cluster (M44), a nice binocular jewel. The ringed wonder is an awesome sight in any telescope. Zoom in on the gas giant to see the globe casting a shadow on the rings. This gives the planet a noticeable 3-D appearance.

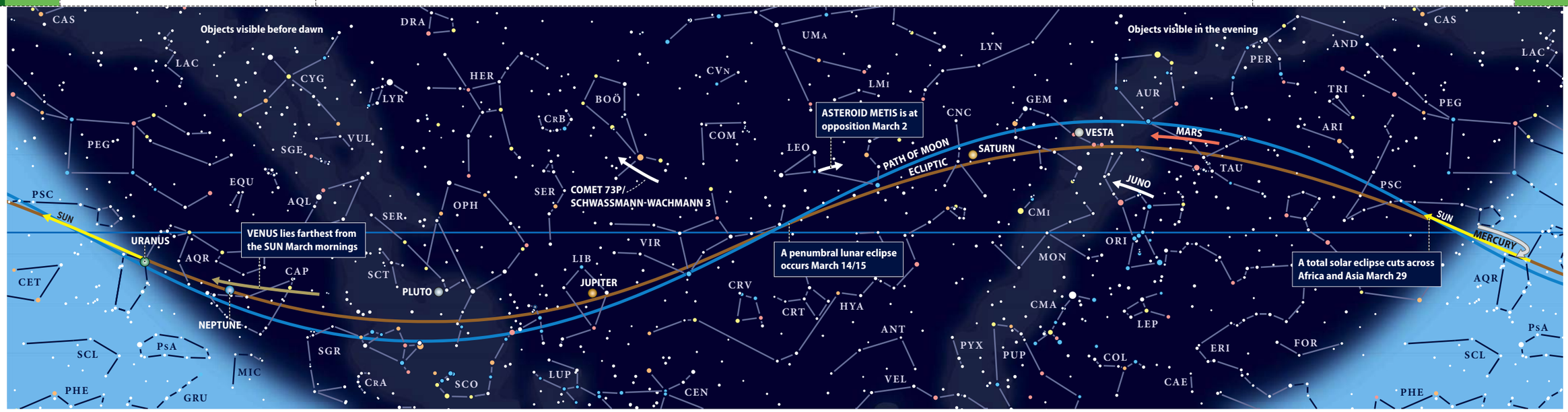
Mars, although it's bright and lies high in the sky, will be a disappointment to telescopic observers. Earth has pulled far ahead of the planet, and all that remains is a tiny, rust-colored dot with barely discernible low-contrast markings. Instead, enjoy the Red Planet's appearance to the unaided eye, as the planet tracks slowly east of the Pleiades star cluster (M45) and north of the similarly colored bright star Aldebaran.

Mark your calendar for April 1. Early that evening, a gorgeous crescent Moon filled with earthshine will pass through the Pleiades. Whether you use binoculars or a telescope, you're sure to get a great view. More details will appear in next month's *Astronomy*.

The spring, or vernal, equinox happens March 20 at 1:26 P.M. EST. This marks the moment when the Sun's center crosses the celestial equator. If the Sun were a point of light, we would have 12 hours of day and 12 hours of night. Because the top peeks above the horizon before the center rises, the day is actually a bit longer than the night. The media seem to enjoy creating hoopla surrounding the equinox. For stargazers in northern climes, however, it's all about spending milder nights under the stars.

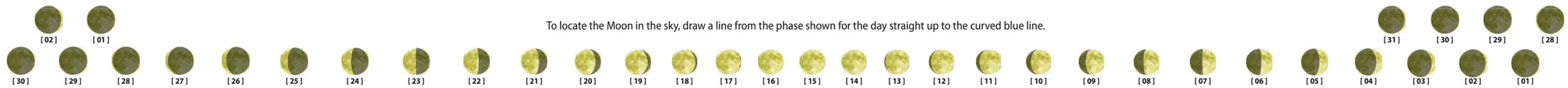
Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



ALL ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

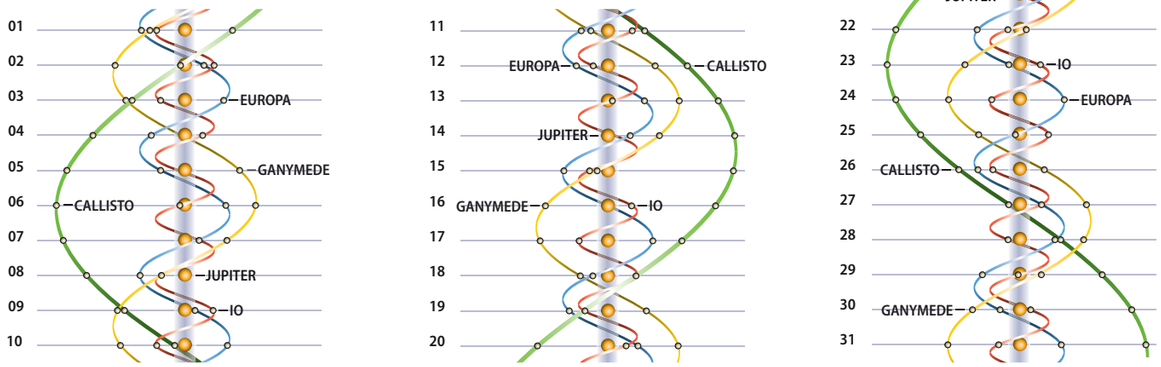


PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	March 1	March 31	March 1	March 31	March 15	March 15	March 15	March 15	March 15	March 15
Magnitude	0.3	0.6	−4.5	−4.2	1.0	−2.3	0.0	5.9	8.0	13.9
Angular size	8.4"	9.0"	33.9"	23.1"	6.3"	41.2"	19.7"	3.3"	2.2"	0.1"
Illumination	27%	34%	35%	52%	90%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.803	0.750	0.493	0.724	1.480	4.791	8.442	21.046	30.859	31.111
Distance (AU) from Sun	0.319	0.458	0.721	0.725	1.615	5.430	9.120	20.078	30.057	31.085
Right ascension (2000.0)	23h43.4m	23h03.4m	19h50.9m	21h42.3m	4h45.4m	15h06.1m	8h28.9m	22h52.5m	21h24.1m	17h46.0m
Declination (2000.0)	0°58'	−6°36'	−16°18'	−12°32'	24°06'	−16°08'	19°48'	−7°58'	−15°26'	−15°50'

S W E N 10"

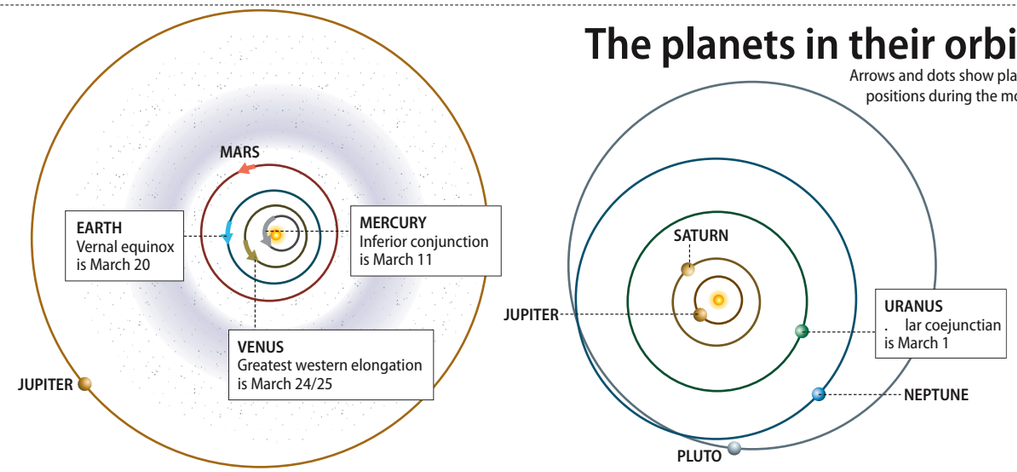
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EST on date shown. South is at top to match the view through a telescope.



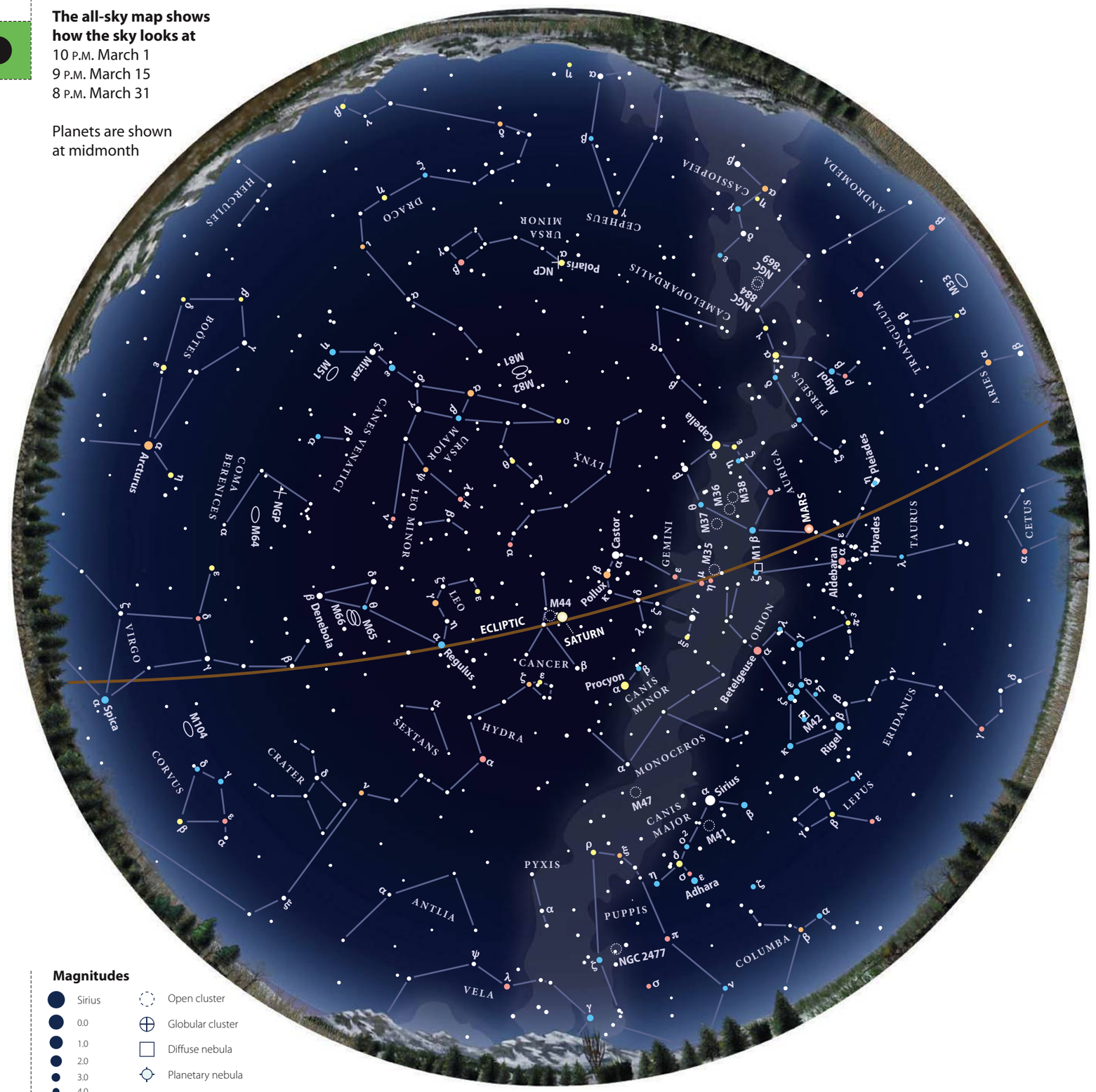
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
10 P.M. March 1
9 P.M. March 15
8 P.M. March 31

Planets are shown at midmonth



Magnitudes

Sirius	Open cluster
0.0	Globular cluster
1.0	Diffuse nebula
2.0	Planetary nebula
3.0	Galaxy
4.0	
5.0	

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

march 06

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			[01]	[02]	[03]	[04]
[05]	[06]	[07]	[08]	[09]	[10]	[11]
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[26]	[27]	[28]	[29]	[30]	[31]	

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 Uranus is in conjunction with the Sun, 6 A.M. EST

02 Asteroid Metis is at opposition, 5 P.M. EST

06 The Moon passes 3° north of Mars, 2 A.M. EST

First Quarter Moon is at 3:16 P.M. EST

10 The Moon passes 4° north of Saturn, 1 P.M. EST

Mars passes 7° north of Aldebaran, 7 P.M. EST

11 Mercury is in inferior conjunction, 10 P.M. EST

12 The Moon is at apogee (252,450 miles from Earth), 8:45 P.M. EST

14 Full Moon is at 6:35 P.M. EST; penumbral lunar eclipse

17 The Moon passes 0.3° north of Spica, 6 A.M. EST

19 The Moon passes 5° south of Jupiter, 9 A.M. EST

20 Vernal equinox is at 1:26 P.M. EST

The Moon passes 0.3° south of Antares, 10 P.M. EST

22 Last Quarter Moon is at 2:11 P.M. EST

25 Venus is at greatest western elongation (47°), 2 A.M. EST

The Moon passes 6° south of Venus, 6 P.M. EST

26 Venus passes 1.9° north of Neptune, 4 P.M. EST

27 The Moon passes 2° south of Mercury, noon EST

28 The Moon is at perigee (223,177 miles from Earth), 2:13 A.M. EST

29 New Moon is at 5:15 A.M. EST; total solar eclipse

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

THE DEEP SKY

Viewing 109 objects in a Messier marathon may seem like a full night, but a surprising amount of time remains to see other sights — like a nice comet.

Run a marathon

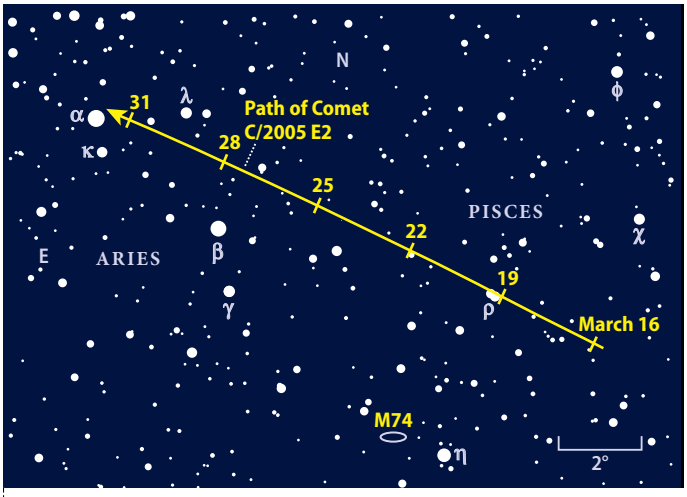
March is the month when many stargazers attempt an annual Messier marathon. Why now? Most Messier objects just happen to be located away from the Sun's glare at this point in Earth's orbit, but you can't deny the fact that spring nights are much more enjoyable than winter's debilitating cold.

It all started in the 1700s, when French comet-hunter Charles Messier kept stumbling across star clusters and nebulous patches while searching for and following comets. His catalog of non-comets has stood the test of time as the "top 109" deep-sky objects. Many splendors still go by their Messier number. After all, M42 is easier to say than "The Great Orion Nebula."

In the 1970s, observers realized it's possible to see all the Messier objects in one night, from dusk to dawn, and Messier marathoning was born. "Take a deep-sky treasure hunt" on page 74 will help you plan an observing strategy. And plan you must; otherwise, some objects will set while you search for others.

Because moonlight and city skyglow will hide the fainter Messier objects, you need to head to the country during the last week of March, when the Moon is almost new, to have a successful Messier marathon.

Author and observer David Levy discourages "sprinting." There's time to take a couple of minutes to jot down some notes on the structure and features of each Messier object. If you start with some of the bright, splashy star clusters early in twilight, you won't have to rush later on. There's even time for a refreshing nap after midnight, before the homestretch of summer clusters and nebulae toward dawn.



ASTRONOMY: ROEN KELLY

COMET C/2005 E2 (McNAUGHT) passes near the galaxy M74 this month. The two look similar through a small scope.

TODD BOROSON/NOAO/AURA/NSF

SPIRAL GALAXY M74 looks beautiful, but its low altitude makes it tough to find during a Messier marathon.

The spiral galaxy M74 is one of the most challenging objects during the marathon. You'd think with stats like a magnitude of 9.4 and a diameter of 11' (one-third the Moon's apparent diameter), it would be easy to see. However, when you look for it during twilight, as you must this time of year, the outer arms and circular glow disappear, leaving only the galaxy's inner region as a faintish "star" with a small halo.

Take a moment to reflect on the fact that Messier didn't have a clue about M74's true nature. Lurking inside the bright core is a quiescent black hole, and the misty light surrounding it is not at all like a morning fog — it's the output of billions of stars shining at a staggering distance of 30 million light-years. We're fortunate to live at a time when, for the most part, we can understand what we're viewing.

A cometary interlude

Coincidentally, Comet C/2005 E2 (McNaught) floats just a few degrees from M74. Because you need to use the brighter stars of Aries as a starting point anyway, give the comet a look. Forget the marathon for 5 minutes, and experience a true Messier moment by observing a comet. At 10th magnitude, Comet McNaught will appear somewhat similar to the core of M74. You should see the comet as an almost stellar point, called the false nucleus, cocooned in a pale shroud of sunlit dust.

Whoa, look at the time! Better line up your next object and get hopping. If you have a go-to telescope, take advantage of this modern technology to locate each Messier object quickly. That way, you can return home with pages of comparative notes instead of a messy sheet littered with a bunch of check marks.

THE PLANETS

All evening long, spectacular views of Saturn await observers with telescopes. The ringed world will keep planetary enthusiasts happy until mighty Jupiter takes center stage after midnight.

March gradually brings springtime weather to most of the United States. The later sunsets begin to catch up with Mercury as its elongation from the Sun rapidly diminishes. During the first week of March, you can find the innermost planet low in the west shortly after sunset. It continues its fine display that began in early February. Mars remains among the stars of Taurus the Bull; while in the eastern sky, Saturn climbs higher, ready for some fine evening viewing with telescopes.

You'll want to spy **Mercury** early this month because it drops out of sight by March 6. On the 1st, the planet shines at magnitude 0.3 and lies 12° below a slender crescent Moon. Through a telescope, you can compare the Moon's 6-percent illumination to Mercury's thicker crescent, now about one-quarter lit. However, Mercury's crescent wanes each day while the Moon's waxes. On March 2, for example, the lunar crescent has grown to 12-percent lit, compared with Mercury's 19 percent. After March 4, when Mercury sets an hour after the Sun and shines at 2nd magnitude, the planet becomes hard to spot.

Mercury slides between the Sun and Earth March 11, then re-emerges in the morning sky during the month's final week. This will be an unimpressive appearance, however. Mercury remains fainter than magnitude 0.8 until March 27, when a thin crescent Moon lies 5° south of the planet. The fast approaching twilight makes the Moon difficult to spot unless you have a clear and unobstructed eastern horizon. Mercury rises an hour after Venus and hugs the horizon until becoming lost in the dawn glow.

Taurus the Bull looks like it has two eyes this month. Aldebaran, the constellation's brightest star and traditionally the eye of the Bull, shares the assignment with **Mars**. The Red Planet appears prominent 7° north of Aldebaran. Both objects shine at magnitude 0.8 in early March, although Mars fades by half a magnitude during the month.

Watch the sky March 5, when the crescent Moon lies between Mars and the Pleiades star cluster (M45). Mars continues to wander eastward across Taurus and, by the 31st, lies between the two stars marking the Bull's horns, Beta (β) and Zeta (ζ) Tauri.

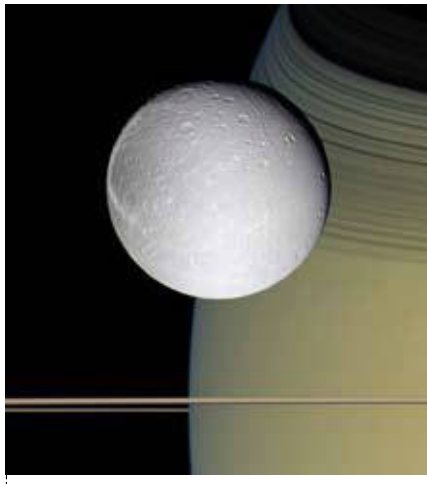
Telescopically, Mars is far past its best. The disk spans a mere 6", too small for most scopes to show much detail, especially under the typically turbulent springtime skies. Its appearance as a bright "star," however, will continue for several weeks.

Saturn has a prime location for evening viewing. An hour after sunset, it lies high in the southeast. The ringed planet shines at magnitude 0.0 and stands out among the faint stars of Cancer the Crab. Saturn passed opposition in late January, so it remains close to its best during March.

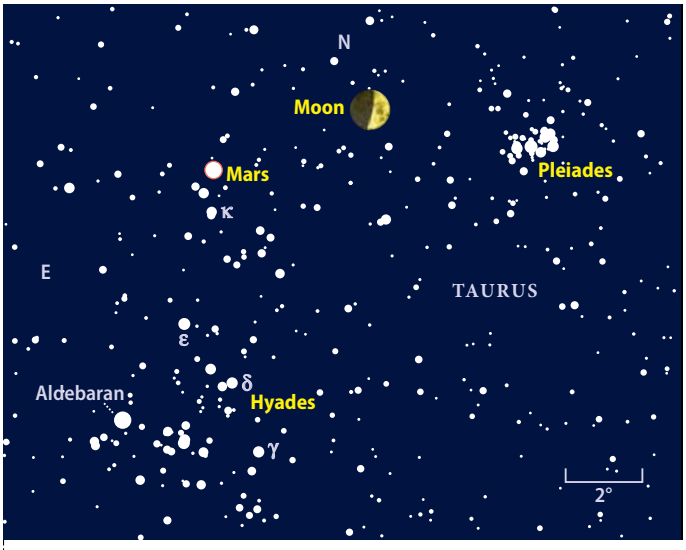
On the 10th, the waxing gibbous Moon serves as a guide to finding Saturn. In the early evening, look for the bright, starlike object 5° right of the Moon. A view through binoculars reveals the Beehive star cluster (M44) shimmering 2° east of the planet. Saturn's motion carries it to a point 3° west of M44 by March 31. The planet halts its retrograde motion against the stars in early April and returns to direct motion, which will bring it south of M44 in June.

The best telescopic targets in this planet's system, after the spectacular, 44"-diameter rings, are Saturn's numerous moons. The moons dance a continuous waltz around the planet. Try to identify which one is which. This rewarding challenge takes on an added significance thanks to our newfound knowledge of the moons garnered by the Cassini spacecraft.

Twice each month, Titan makes a complete orbit of the

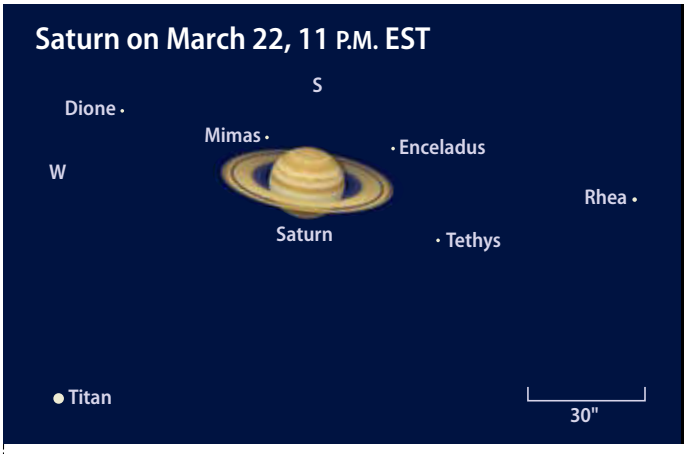


DIONE'S BATTERED TERRAIN stands out against Saturn's cloud tops in this Cassini image. NASA/JPL/SSI



ASTRONOMY: ROEN KELLY

MARS SLIDES NORTH of Aldebaran in Taurus this month, giving the Bull a pair of ruddy eyes. The Moon joins the scene March 5.



ASTRONOMY: ROEN KELLY

YOU CAN SPY DIONE, and half a dozen other saturnian moons, through a 6-inch or larger scope with good optics.

planet. Saturn's largest moon is easy to see because it glows brightly at magnitude 8.4. Titan lies north of Saturn March 5 and 21, and south of the planet March 13 and 29. A much dimmer moon, Iapetus, lies near Titan March 29. Iapetus changes brightness as it turns its dark or light side toward us. At greatest western elongation, the moon appears relatively bright, at magnitude 10.1. This occurs in the second week of March. Even in a small telescope, you should see Iapetus easily to Saturn's west. During the latter half of March, the moon dims slowly. See how long you can track it.

Other moderately bright moons lie closer to Saturn than Titan and Iapetus. Tethys, Dione, and Rhea each glow at 10th magnitude. The icy world Enceladus poses more of a challenge by glowing at magnitude 11.8. It lies close to the bright rings and skips around Saturn in less than a day and a half.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

Giant **Jupiter** rises before midnight but doesn't offer its best views until it climbs well above the horizon in the early morning hours. It stands 30° high in the southeast around 3 A.M. local time in early March, and by 1 A.M. late in the month. Later in the morning, you also can spot Antares, Scorpius' brightest star, rising well to Jupiter's lower left. The planet shines at magnitude –2.3 and dominates the rather dim constellation Libra the Scales. Because Jupiter lies at a southerly declination, observers at mid-northern latitudes won't see it climb higher than about 40° all year.

Unlike Saturn, Jupiter's disk brims with features that small telescopes — combined with a patient observer — can show. Jupiter's large, 41"-diameter disk also helps. Obvious at first glance are two dark belts that run on either side of Jupiter's equator. These are the North and South Equatorial Belts (NEB and SEB).

Jupiter's other features are more subdued and often require a trick to view. The trick is to keep watching the planet for an extended period — which gives time for your eye to adapt to momentary improvements in "seeing." Seeing describes the steadiness of the air, from your telescope to the edge of Earth's atmosphere. Turbulence is the enemy of observers, yet moments of steady seeing occur frequently. Jupiter's cloud tops reveal astonishing detail during these fleeting moments, so make the most of them.

Other observable dark features include the North and South Temperate Belts (NTB and STB). The South Tropical Zone lies between the SEB and the STB. The Great Red Spot resides in this zone and indents into the southern edge of the SEB. The spot's current pale salmon-pink color makes it a subtle feature in the eyepiece.

Jupiter rotates in less than 10 hours, so new features appear each hour. Tracking features day after day is the best way to become familiar with the giant planet's appearance.

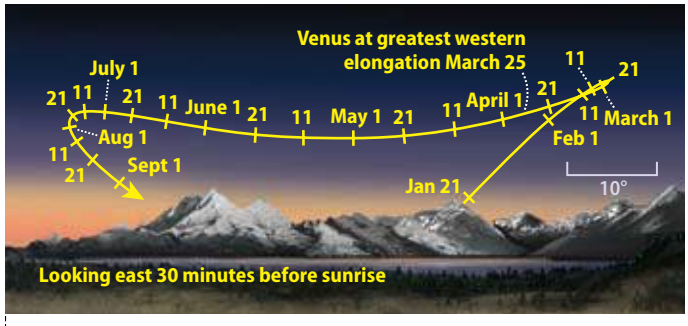
If the idea of standing out in the cold for extended periods doesn't appeal to you, technology can come to your aid. Using a webcam, you can capture Jupiter through a telescope at 30 frames every second — enough to have dozens of frames that freeze the air's turbulent motion and allow those random moments of great seeing to be captured forever.

Clever stacking software, such as the freeware *Registax*, optimizes the images to save only those frames that show sharp detail on the planet's disk. Store no more than 2 minutes of video at a time because Jupiter's fast rotation will start to blur details. Tedious pencil sketches at a cold eyepiece can now be replaced with endless happy hours processing images at a warm computer screen.

About 2 hours before the Sun rises, **Venus** pokes above the east-southeastern horizon. The planet shines at magnitude –4.4, making it the brightest point of light in the sky.

Venus' telescopic appearance changes quickly during March. On the 1st, the planet's disk measures 34" across and appears 35-percent lit. By month's end, it spans 23" and looks a shade over half-lit. A waning crescent Moon passes to the right of the "morning star" March 25.

Mainly of academic interest is Neptune's location 2° south of Venus March 26. Neptune's dim, 8th-magnitude globe will be a challenge to see because of its low altitude and the rapidly advancing twilight.



ASTRONOMY: TERRI FIELD

VENUS CLIMBS HIGHEST in the morning sky during March, when it reaches its peak for this predawn apparition.

METEORS AND MOONS

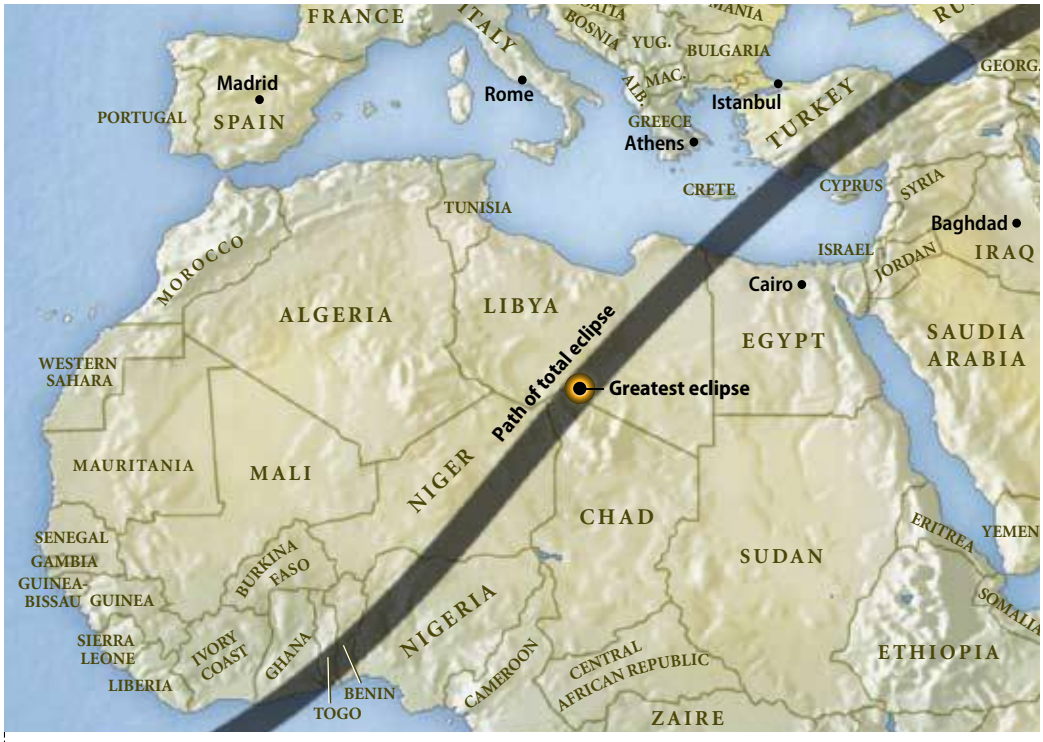
The Moon passes in front of the Sun March 29, bringing the best solar eclipse until 2009. When a lit Moon is on display, look for a prominent crater in the ancient southern highlands.

A totally grand eclipse

A list of nature's most spectacular events would have to include a total solar eclipse. On March 29, observers can see more than 4 minutes of totality, the longest duration until July 2009.

The path of totality begins on Brazil's coast. After crossing the Atlantic, the track traverses northern Africa, the eastern Mediterranean, and parts of Asia before ending in Siberia.

The highlights of any eclipse come just before, during, and after totality. Look for Baily's beads as the last rays of sunlight peek through lunar valleys. The diamond ring is the final glint of this light. During totality, watch for reddish prominences and the ethereal corona. After totality, the diamond ring and Baily's beads appear once more. To avoid blindness, view the partial phases only indirectly or with a proper solar filter.



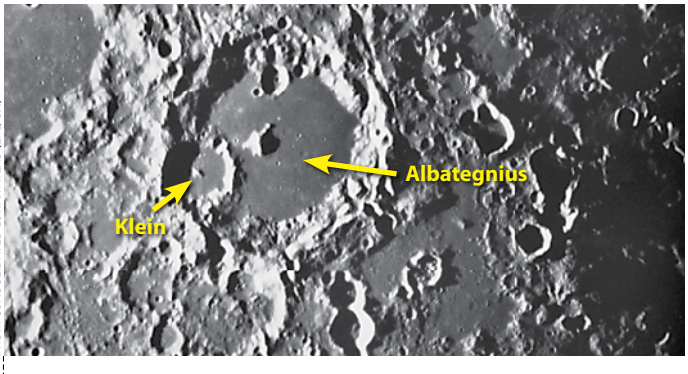
ASTRONOMY: ROEN KELLY

DARKNESS COMES AT MIDDAY March 29 to those along a narrow path that crosses Africa and Asia.

A dusty solar system

No significant meteor shower takes place during March. The general background of sporadic meteors runs about 7 per hour, with occasional fireballs.

Although you won't see much interplanetary dust burning up in Earth's atmosphere, March evenings are prime time for viewing sunlight reflecting off dust in the inner solar system. This faint glow, called the zodiacal light, lies in the plane of Earth's orbit, so it follows the constellations of the zodiac. Look for the zodiacal light after twilight completely fades away. You'll see it only under the darkest sky, and low humidity increases its visibility.



FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

LUNAR CRATER ALBATEGNIUS suffered many hits over billions of years but none bigger than the one that gouged out crater Klein.

Eye on Albategnius

Lying in the ancient highlands of the Moon's southern hemisphere, Albategnius shows its age. The 85-mile-wide crater sits east of Mare Nubium, not far from the better known trio of Ptolemaeus, Alphonsus, and Arzachel. The crater's western side sports a more recent crater: Klein, which measures 27 miles across. Many smaller craters have reshaped Albategnius' northern wall.

Note the almost polygonal shape of Albategnius' northeastern, northwestern, and western walls. This could reflect a fault system underlying the entire region. Many pits and a pronounced central peak mar the crater's otherwise smooth floor. Several linear scars cross this region of the Moon, apparently radiating from the huge Mare Imbrium basin. These scars form an almost permanent record of a huge impact in the Moon's distant past. The Sun rises over Albategnius near First Quarter phase March 6.

COMETS AND ASTEROIDS

The early spring sky offers a nice sample of comet and asteroid apparitions that should whet observers' appetites for some highlights later this year.

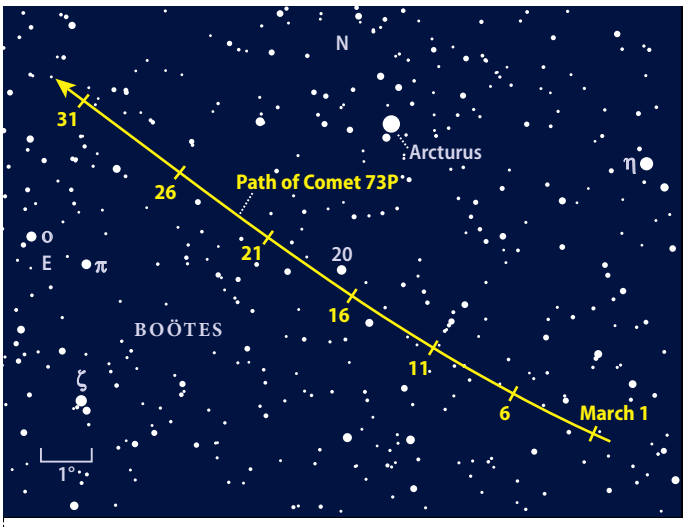
A possible bright comet

The only thing predictable about comets is that they are unpredictable. That wisdom hit home with the appearance of Comet Kohoutek in the 1970s. And it certainly applies to Comet 73P/Schwassmann-Wachmann 3. This could be its last trip through the inner solar system. In 1995, the comet's nucleus split as it rounded the Sun, just inside Earth's orbit. Then, during the comet's most recent return in early 2001, astronomers observed the three biggest components (B, C, and E). They were much brighter than predicted, probably because the breakup exposed fresh ice to sunlight.

This year, many astronomers think component C will be the only observed survivor. How bright will it get? Some comet experts predict it will peak near 7th magnitude, making it a nice binocular object. Others think the fragment will flare like other comets have done, and perhaps reach 1st or 2nd magnitude. That would make it an easy target for the unaided eye. The possibility also remains that it might dissolve into a low-contrast cloud that's all but invisible to comet-watchers.

At the end of March, when the Moon is out of the late evening sky, Schwassmann-Wachmann 3 moves slowly near Arcturus above the eastern horizon. If we're lucky and the nucleus is active, it will glow around 9th magnitude. This is within range of a small scope from a dark site. Otherwise, it might be a 13th-magnitude diffuse blob, challenging in even a 16-inch scope.

The positions shown on the chart below may be off slightly because the forces that caused the comet to break up may also delay its return.



ASTRONOMY: ROEN KELLY

A BRIGHT VISITOR could light up the spring sky, but no one knows how bright Comet 73P/Schwassmann-Wachmann 3 will become. This month, it passes south of the bright star Arcturus.

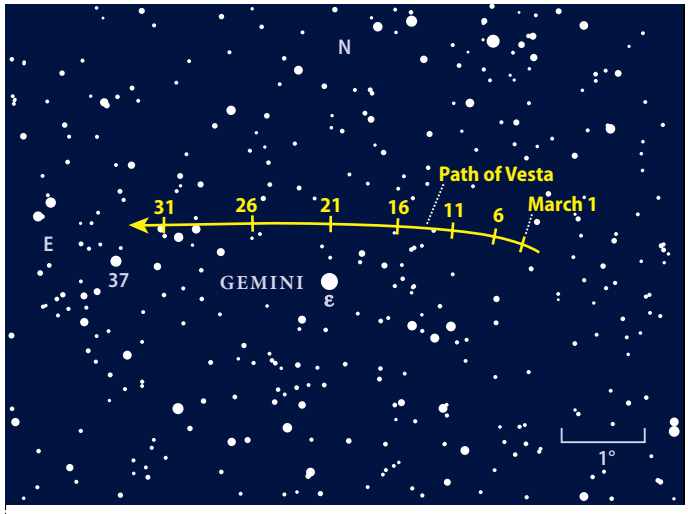
A pair of German astronomers — Arnold Schwassmann and Arno Wachmann — discovered this comet May 2, 1930, in the course of a photographic search for asteroids. It appeared as a diffuse, 9.5-magnitude glow. Dust trails from the comet produced a shower of 60 to 70 meteors per hour June 9/10, 1930. This was anticipated because of the comet's close pass to Earth. Unfortunately, dust-trail models predict Earth will not pass through a dense trail this June, despite the parent comet's close passage.

Reliable rock

With a few notable exceptions, asteroids lead much simpler lives than comets. The third largest in the asteroid belt, Vesta, spans 320 miles and is slightly out of round. It reflects about 35 percent of the light that falls on it, which makes it the brightest asteroid whenever it approaches Earth.

Now that Earth is pulling away from Vesta, the asteroid fades from magnitude 7.4 to 7.8 during March. This is well within reach of a small scope, an excellent instrument for finding the asteroid. Apart from four or five background stars near Epsilon (ε) Geminorum, Vesta is the brightest object in the field. Make a quick sketch on one night, then come back a couple of nights later to confirm that it moved. By month's end, the asteroid lies near a trio of similarly bright stars.

Tracking asteroids this month will give you practice for August, when three of these flying mountains hit their peaks in the same area of sky as the gas-giant planet Neptune.



ASTRONOMY: ROEN KELLY

ASTEROID VESTA lies near Epsilon (ε) Gem, which makes an excellent guide to the 7th-magnitude minor planet.

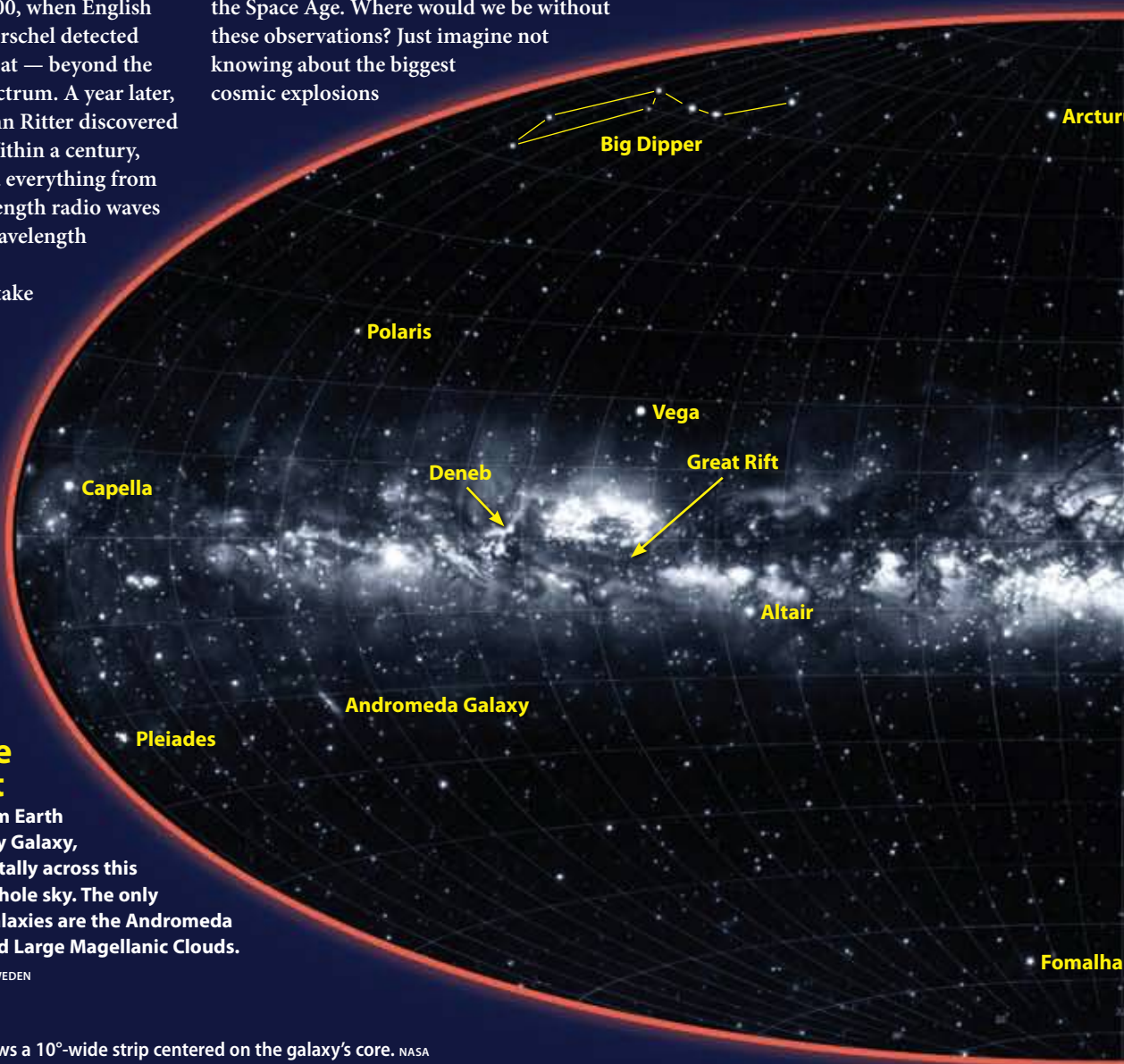
Astronomy magazine

The universe across the spectrum

From radio waves to gamma rays, astronomers use all types of light to explore the cosmos. /// BY RICHARD TALCOTT

People have always explored the night sky with their eyes, but the eye sees only visible light. Scientists didn't know other forms of light existed until 1800, when English astronomer William Herschel detected infrared radiation — heat — beyond the red end of the Sun's spectrum. A year later, German physicist Johann Ritter discovered ultraviolet radiation. Within a century, scientists had identified everything from low-energy, long-wavelength radio waves to high-energy, short-wavelength gamma rays.

Astronomers didn't take advantage of these new wavelengths until 1931, when American Karl Jansky accidentally discovered the Milky Way's radio emission. Earth's atmosphere lets through visible light and radio waves but little else, so viewing other wavelengths had to wait for the Space Age. Where would we be without these observations? Just imagine not knowing about the biggest cosmic explosions — gamma-ray bursts — or the cosmic microwave background radiation that helped prove the Big Bang happened.



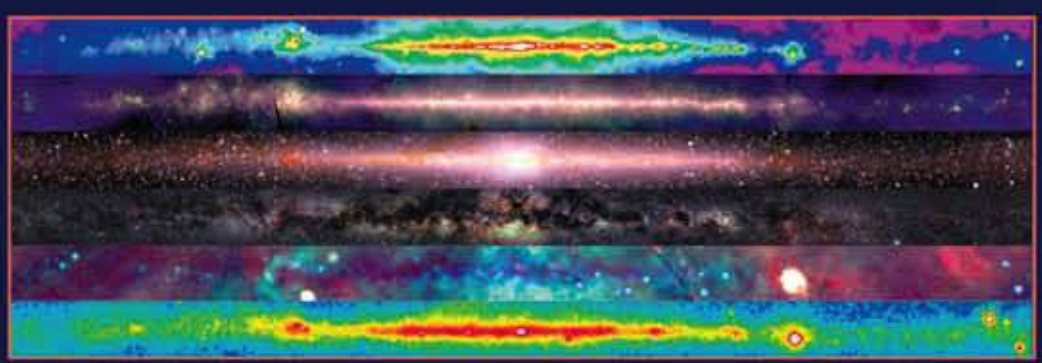
▶ The universe in visible light

Most of what we see from Earth belongs to the Milky Way Galaxy, whose disk runs horizontally across this naked-eye view of the whole sky. The only easily visible external galaxies are the Andromeda Galaxy and the Small and Large Magellanic Clouds.

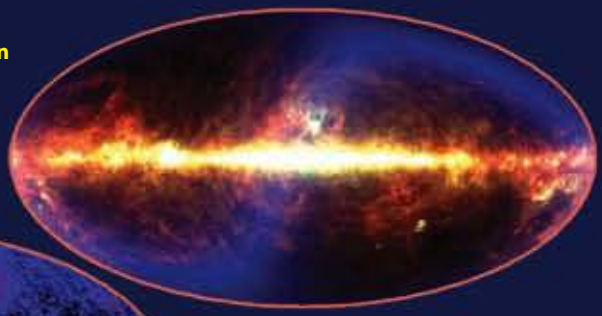
LUND PANORAMA OF THE MILKY WAY, SWEDEN

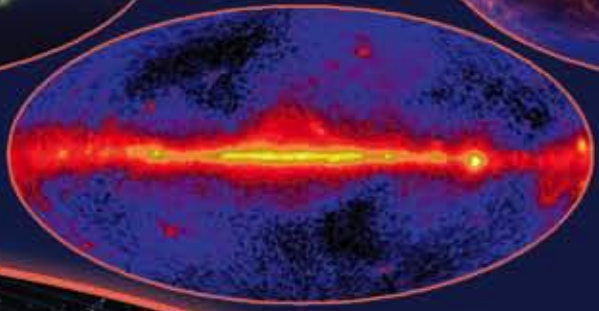
▼ The Milky Way's plane

Each wavelength band shows a 10°-wide strip centered on the galaxy's core. NASA



◀ Near-infrared radiation
At wavelengths around 2 micrometers (μm), half a billion cool stars light up the Milky Way. 2MASS/J. CARPENTER, T. H. JARRETT, AND R. HURT

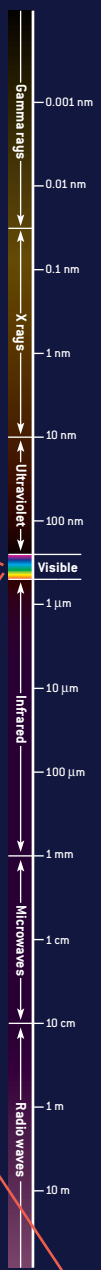


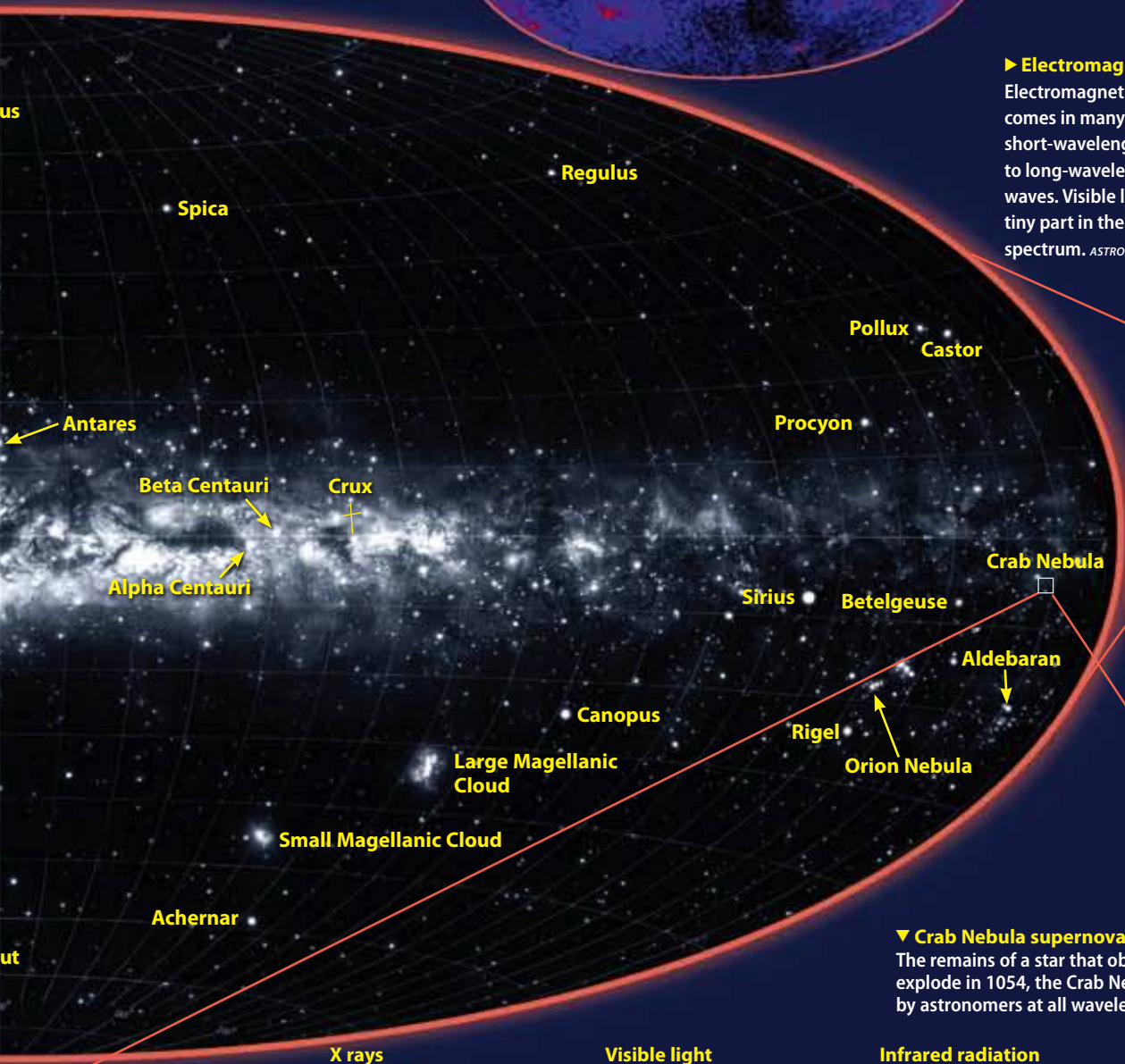


Gamma rays ▶
At the highest energies, cosmic-ray interactions dominate the Milky Way's disk. EGRET (NASA/CGRO)

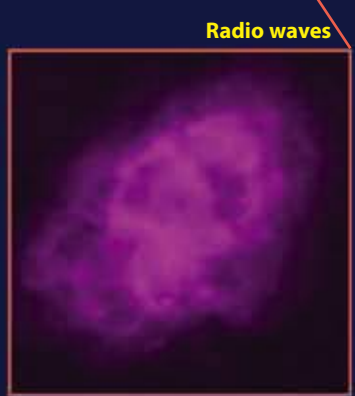
▲ Far-infrared radiation
Near 100 micrometers, dust in the Milky Way's disk glows brightly. M. HAUSER (STScI), COBE, AND NASA

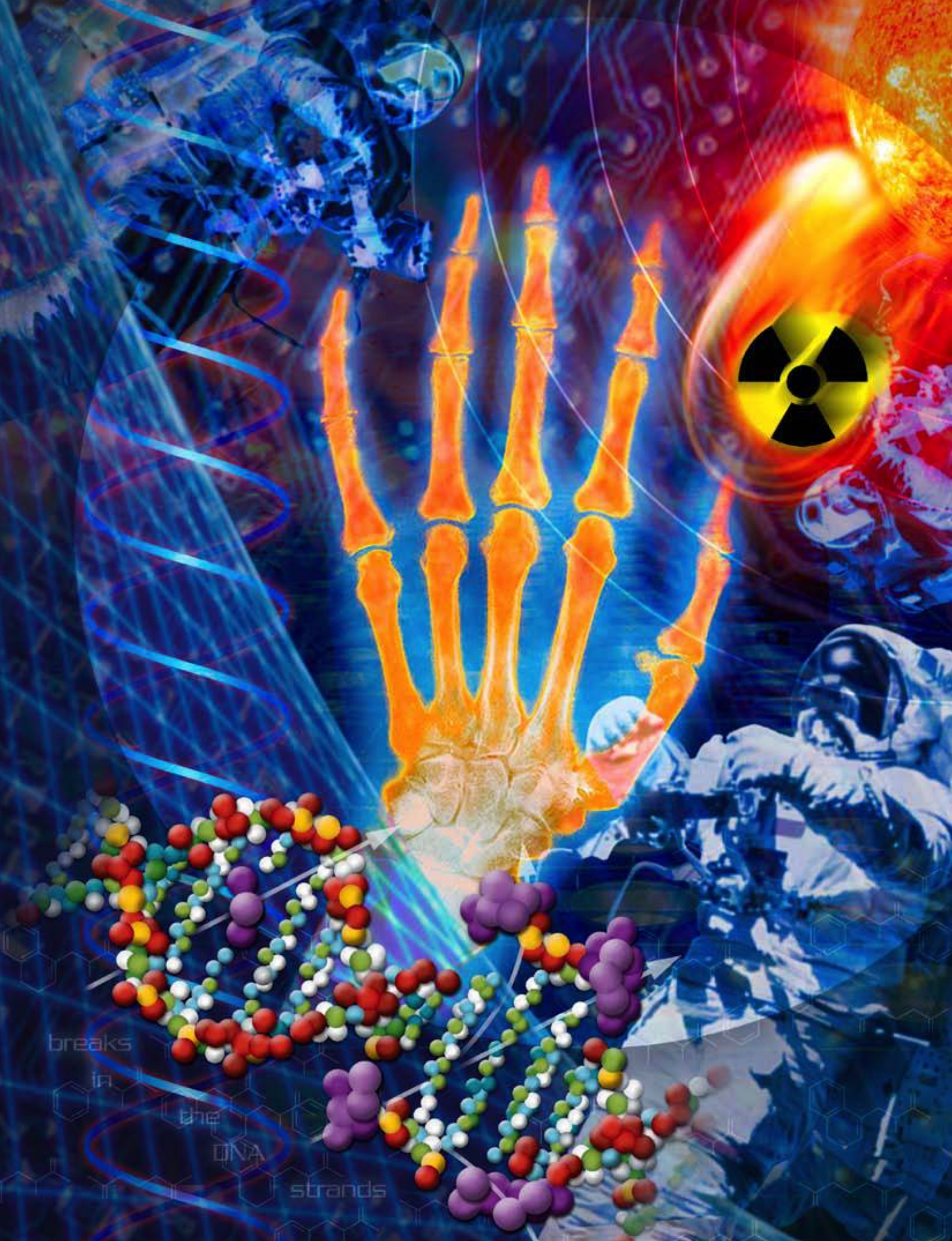
▶ Electromagnetic spectrum
Electromagnetic radiation comes in many forms, from short-wavelength gamma rays to long-wavelength radio waves. Visible light occupies a tiny part in the middle of the spectrum. *ASTRONOMY*: ROEN KELLY





▼ Crab Nebula supernova remnant
The remains of a star that observers saw explode in 1054, the Crab Nebula is viewed by astronomers at all wavelengths.




breaks
in
the
DNA
strands

Who knows what dangers lurk in space?

Radiation can damage DNA and even kill — and space is filled with it. How can we protect astronauts? /// BY JACQUELINE GARGET

How much radiation the human body can tolerate is a crucial factor if NASA plans to send astronauts back to the Moon, and eventually to Mars and beyond. The agency needs to find a way to protect astronauts on their journeys. Radiation is damaging to spacecraft and, of course, to humans. From the digestive system going haywire to the central nervous system shutting down, the effects of radiation exposure are serious concerns of crewed space missions.

THE SUN SPEWS X-rays and high-energy particles during a flare, which forces astronauts who are outside Earth's protective field to take cover. Radiation easily penetrates skin and can ravage DNA. The outcome isn't pretty: mutated cells that can lead to cancer, radiation sickness, or defects in the genetic sequence.

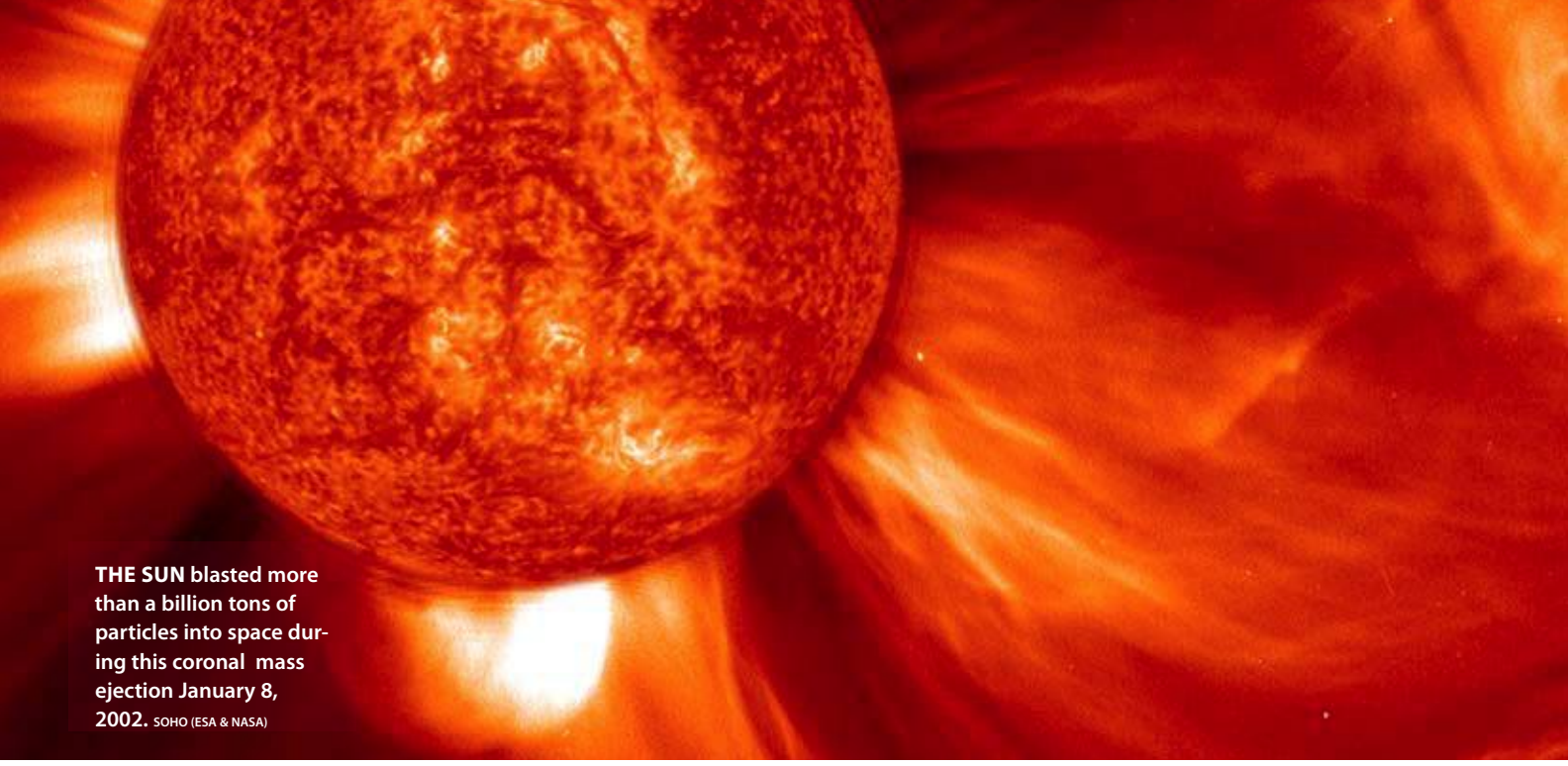
ASTRONOMY: KELLIE JAEGER; SUN PHOTO: SOHO (ESA & NASA)

Shielded planet

Earth protects us from most of the radiation that fills the universe. Our planet's magnetic field deflects or traps potentially harmful energetic charged particles from the Sun. Trapped particles spiral eternally between the north and south magnetic poles as part of Earth's Van Allen radiation belts. Earth's atmosphere scatters and absorbs cosmic rays — further protecting life on our planet.

Fortunately, Earth's radiation belts extend far enough into space that the International Space Station (ISS) can orbit inside them, within the magnetosphere. In effect, Earth provides a natural force field to protect ISS astronauts from *most* incoming radiation. In fact, except for the week-long missions to the Moon, all manned spaceflights so far have taken place within the protection of Earth's magnetosphere.

Space radiation consists of naked atoms. As these atoms are accelerated to almost the speed of light in space,



THE SUN blasted more than a billion tons of particles into space during this coronal mass ejection January 8, 2002. SOHO (ESA & NASA)

THE SUN'S MOST INTENSE X-RAY FLARES

X-class	Date	Time
28	Nov. 4, 2003	19h50m
20	Aug. 16, 1989	1h17m
20	Apr. 2, 2001	21h51m
17.2	Oct. 28, 2003	11h10m
17.1	Sept. 7, 2005	17h40m
15	Jul. 11, 1978	10h58m
15	Mar. 6, 1989	14h10m
14.4	Apr. 15, 2001	13h50m
13	Apr. 25, 1984	0h01m

X-class: the scale used to classify the most energetic solar flares, based on their brightness in the X-ray spectrum (not all flares are X-class)
Time: Universal Time (UT) of peak flare intensity

they are stripped of their electrons (ionized) — and only their nuclei remain. These nuclei have so much energy, they will tear electrons off any matter they impact. If they hit a spacecraft, or worse, a human body, they may cause considerable damage.

Neither the Moon nor Mars has a protective magnetic field, but the solid mass of each world provides some shielding. Space radiation can hit astronauts on the Moon or Mars only from above. In free space, radiation comes from every direction.

The Moon doesn't have any atmosphere; Mars has some. Even though it's less than 1 percent as dense as Earth's, the martian atmosphere still manages to stop most incoming solar particles. Unfortunately, Mars' thin atmosphere allows cosmic rays — high-energy particles in space — to reach the planet's surface. So, radiation protection for humans traveling outside Earth's magnetosphere is an important concern — and a significant challenge.

Harmful particles

Two main sources of space radiation exist. The first, and most obvious, is our Sun. The Sun produces a constant stream of particles called the solar wind. The Sun runs on a cycle of approximately 11 years, during which it oscillates between being relatively "quiet" to being a raging monster. At solar maximum, sunspots cover the Sun's surface. Flares and coronal mass ejections (CME) occur frequently, hurling billion-ton clouds of energetic matter into space.

A flare occurs when magnetic energy within the Sun builds to a peak near the surface, explodes, and fires a burst of high-energy particles into space.

CMEs occur when magnetic field lines actually snap. A large CME can spew billions of tons of charged particles and hot gas into space at hundreds of thousands of miles per hour.

During both events, the most energetic particles can reach Earth within minutes. Around solar maximum, several CMEs and flares erupt daily. The Sun is approaching a solar minimum (due in 2006), but even this is not a safe time for astronauts. Solar activity, although sometimes low, never stops. Some of the Sun's most violent flares occur years after solar maximum. Eruptions are so unpredictable, and happen so quickly, that space travelers would have little time to react. Flares are more common than CMEs and can cause severe radiation damage. Predicting solar activity is crucial if humans are going to spend more time in space.

The second, and more predictable, source of radiation in space is galactic cosmic rays. Thought to be produced during supernova explosions, these particles bombard our solar system from all directions. These particles' flux rate is low, but they travel fast. Cosmic rays are high-energy protons and nuclei of heavier elements. The nuclei that can significantly affect biological functions range from hydrogen to iron. Heavy nuclei — like iron — are the most dangerous.

"The galactic cosmic rays include particles that are highly ionizing and can cause very significant tissue damage," says Cary Zeitlin, a radiation expert at the Lawrence Berkeley National Laboratory in Berkeley, California. "However, the flux of these particles is quite low." Even an intense solar particle event produces few particles as dangerous. Each individual particle in a

Jacqueline Garget *is a science writer based in the United Kingdom.*

typical solar event causes much less damage than a heavy cosmic-ray ion, but the Sun produces many more particles.

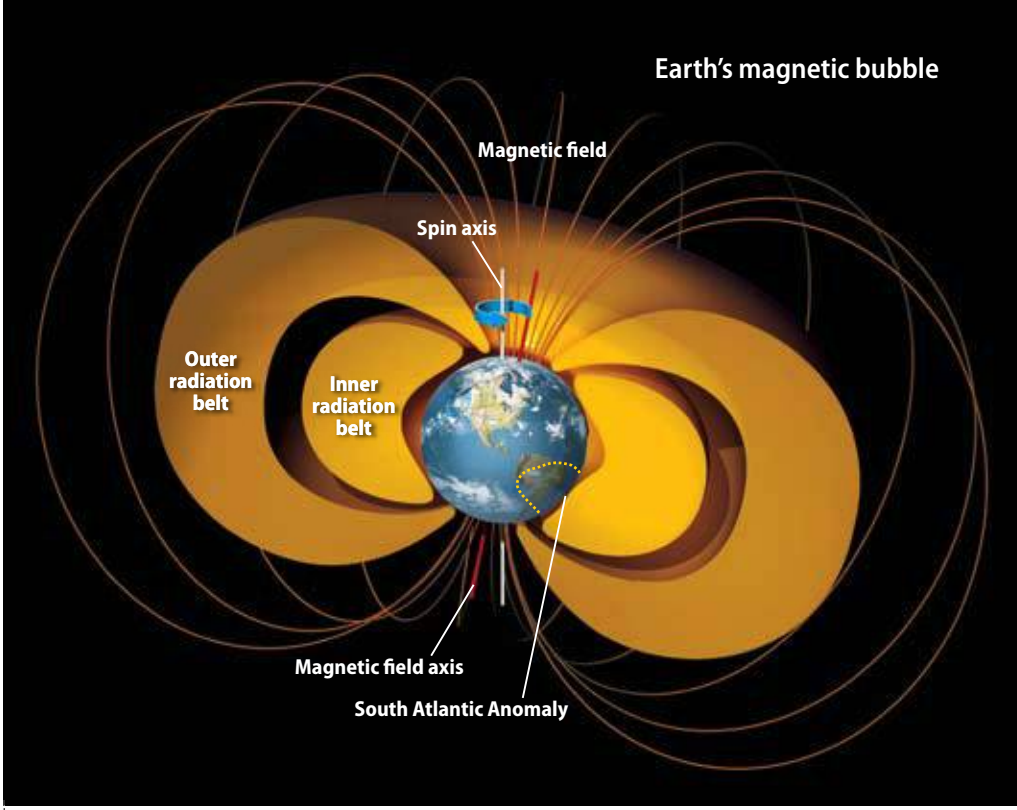
Cosmic rays can easily penetrate spacecraft walls and an astronaut's skin. This is the dominant source of radiation astronauts on ISS must deal with. Cosmic rays will also be the greatest threat to humans on a journey to Mars. And while the risks from the Sun are lower during solar minimum, the danger from cosmic rays increases. As solar activity wanes, the Sun's magnetic field weakens, so it can't deflect cosmic rays as effectively and their intensity increases.

Risky business

Astronauts are classified as radiation workers — those who encounter high radiation levels in their occupation — and NASA has measured radiation exposure on every manned space flight since Project Mercury began in 1961. Crew members aboard the heavily shielded ISS wear dosimeters to monitor radiation levels. The measured radiation can warn crew members of solar disturbances. During an extreme solar flare, an ISS astronaut who doesn't take cover could receive many times the maximum safe annual dose of radiation within a few hours.

NASA's Mars Radiation Environment Experiment (MARIE), aboard the Mars Odyssey spacecraft, collected data on the radiation environment in space and in orbit around Mars before it stopped working. It fell silent during the record solar storms of October 2003 — a victim of intense radiation.

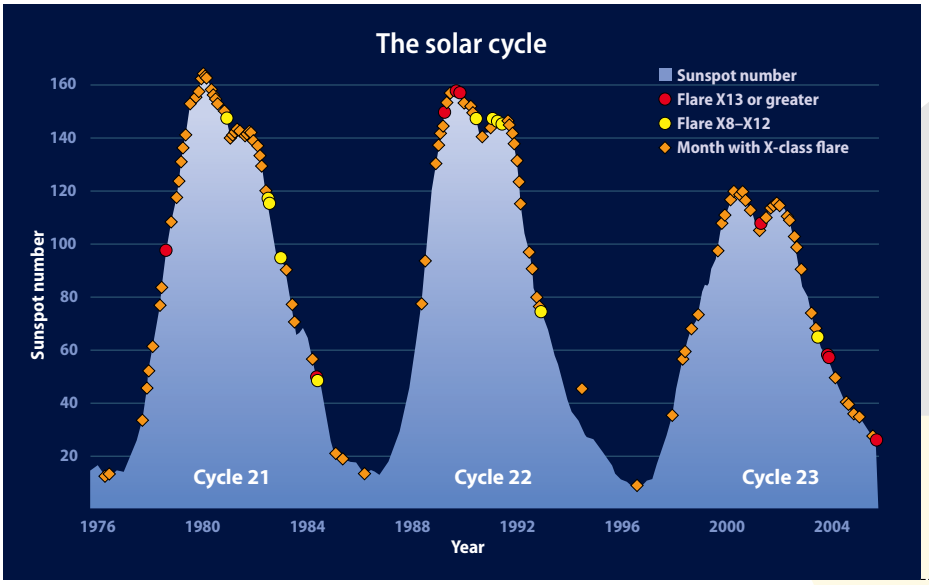
"NASA would like to recover the instrument to allow it to finish radiation mapping at Mars throughout the 11-year solar cycle," says Paul Delaune, a member of the MARIE science team at Johnson Space Center in Houston. "It is an asset that is in place and is inexpensive to operate — we would hate to give up on it." For now, MARIE serves as a relay between the Mars Exploration Rovers and Earth. Once the rovers' missions end, NASA will try to revive MARIE's space-radiation experiment.



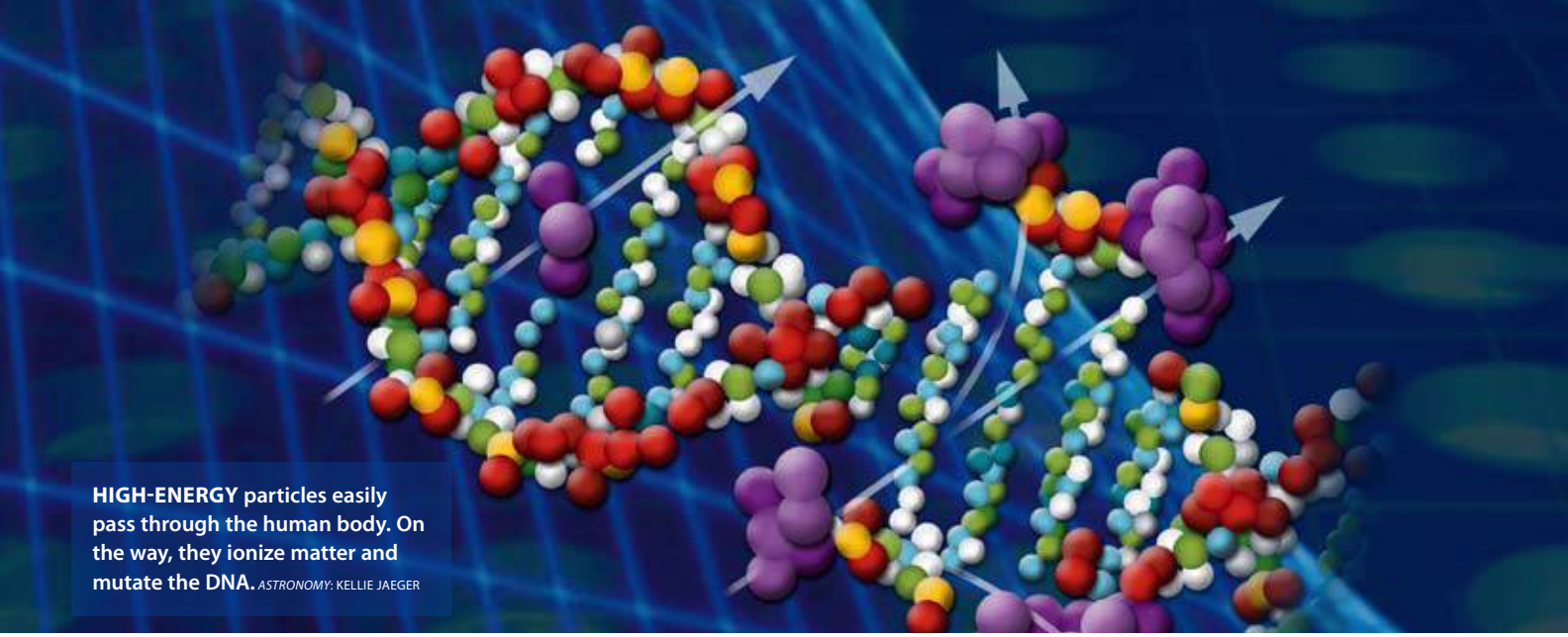
LIFE ON EARTH is protected by the planet's magnetic field and radiation belts that follow the field lines. These belts, called Van Allen radiation belts, trap incoming radiation in a never-ending spiral between the north and south magnetic poles. There are two belts: the inner, composed mostly of protons; and the outer, mostly electrons. The belts line up with Earth's magnetic field, which is tilted 11° away from our planet's spin axis. Because of this tilt, the inner belt passes close to Earth's surface in the south Atlantic Ocean. This is known as the South Atlantic Anomaly. *ASTRONOMY:* ROEN KELLY

Preliminary results suggest astronauts who travel to Mars on a 3-year mission may be exposed to doses near the lifetime safety limits set by NASA. "Personally, I believe the radiation problem is solvable," says Delaune. "The total dose problem has two variables: dose rate and exposure time. The goal will be to reduce one or both to bring the total exposure within acceptable levels."

Advanced propulsion systems could shorten the journey time to Mars, and, therefore, decrease exposure. During the time astronauts are exposed to the space environment, shielding materials will reduce the radiation dose. These materials



THE LAST 30 YEARS have seen three solar cycles. Plotted here is the mean number of sunspots (vertical axis) seen throughout the years (horizontal axis). Colored circles and diamonds show when solar flares occurred. As sunspots increase, so does the number of flares, which are most common at the height of the Sun's activity cycle. The most intense flares can occur any time, but usually on the cycle's downside. *ASTRONOMY:* RICK JOHNSON AFTER FRANCIS REDDY



HIGH-ENERGY particles easily pass through the human body. On the way, they ionize matter and mutate the DNA. *ASTRONOMY*: KELLIE JAEGER

WHAT THE HUMAN BODY CAN WITHSTAND

Radiation isn't present only in space; many objects on Earth are radioactive. Each person receives an exposure of roughly 360 millirem (mrem) per year. (A rem relates the absorbed dose to the biological damage of radiation.) Eighty-two percent of this radiation comes from natural sources: air, soil, food, and the cosmos. The remaining 18 percent comes from human-made sources such as medical and dental X rays, and consumer products (TVs, cellular phones). The maximum radiation dose for occupational radiation workers is 5,000 mrem/year. Here are a few examples of radiation sources and their strengths.

Source	Dose
CT scan (head and chest)	1,100 mrem (1.1 rem)
Average U.S. dose from natural sources	300 mrem/year
Hip X ray	80 mrem
Average U.S. dose from medical sources	53 mrem/year
Radionuclides in the body (e.g., potassium)	39 mrem/year
Mammogram	13 mrem
Natural gas in home	9 mrem/year
Eyeglasses (containing thorium)	6–11 mrem/year
Drinking water	5 mrem/year
Building materials	3 mrem/year
Panoramic dental X ray	1 mrem
Extremities X ray	1 mrem
Living near a nuclear power plant	0.6 mrem/year
Airplane trip at 39,000 ft	0.5 mrem/hour

Much higher doses pose serious health risks. A high dose in a short period of time will cause greater damage than the same amount of radiation spread over years. A 75-rem dose will cause radiation sickness. If you're exposed to between 300 and 500 rem, there's a 50/50 chance of death in 30 days. Such high doses are extremely unlikely for radiation workers and astronauts, and much less for the public. — *Liz Kruesi*

must stop the energetic particles and also prevent secondary radiation from being created by the interaction of the primary radiation with matter.

"The solar proton problem is a simple engineering one," says Frank Cucinotta of NASA's Space Radiation Health Project at the Johnson Space Center. "The energies of protons are such that shielding works. Just a few inches of any material brings the solar proton dose down to a low level."

But the amount of shielding that can be used on a spacecraft has a limited effect against the high-energy cosmic rays. And as Cucinotta says, "As yet, there is no human data to enable scientists to predict the real risks from galactic cosmic rays on long-duration space missions."

The locations where the astronauts spend most time on ISS, such as the sleeping quarters, have additional shielding. Astronauts can move into these areas when they know a burst of energetic particles is coming their way. Scientists have found that materials of low atomic mass, especially hydrogen, work best as radiation shields. Carbon-composite structures with high hydrogen content stop radiation effectively. Proposed designs for advanced spacecraft include surrounding the crew's living space with its water supply (water — H_2O — contains lots of hydrogen) or with liquid hydrogen fuel itself.

Plastics also absorb radiation because they are composed largely of hydrogen. NASA developed a reinforced polyethylene that is 10 times stronger than aluminium, and much lighter. This is already used as shielding on parts of ISS.

Concepts for active shielding — using plasma or a strong magnetic field — are being considered for future spacecraft and for bases on other worlds. One design uses electric fields to deflect charged particles.

Astronauts will also need modified spacesuits — able to withstand the environment, yet lighter, and more flexible than the Apollo suits. Designers may also install small sensors to warn astronauts of a high radiation flux and nearby toxic materials.

More than skin deep

Developing cancer is the main worry for astronauts. NASA measures space-radiation danger in terms of cancer risk. Other effects of long-duration exposure include

EYE-OPENING EXPERIENCE

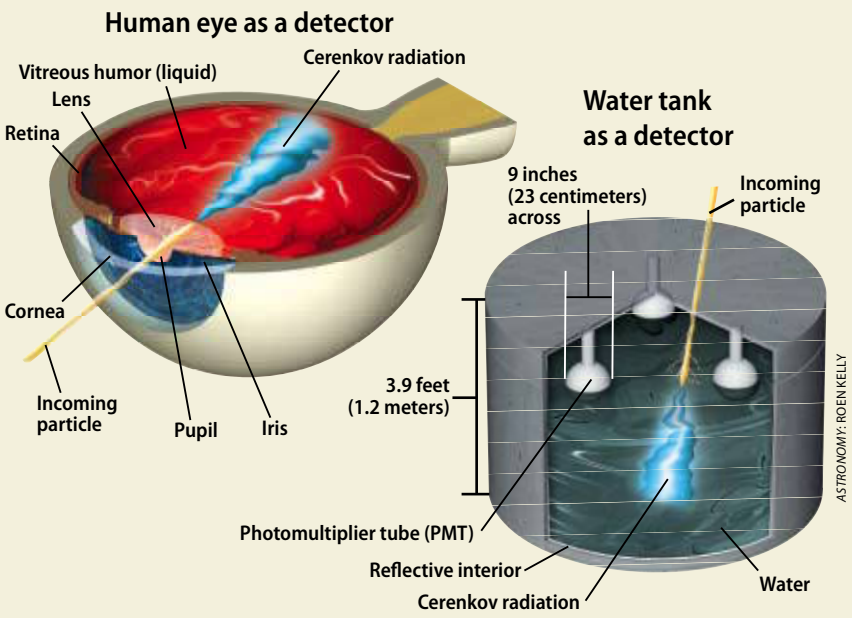
High-energy particles constantly bombard Earth's atmosphere. Most of these particles — called primary cosmic rays — are protons or other atomic nuclei. They interact with nuclei in the atmosphere, producing many lower-energy particles — secondary cosmic rays. This process repeats many times and results in an air shower.

If the primary cosmic ray's energy is intense enough, the particles created in the air shower will arrive at Earth's surface. These particles are mainly muons, electrons, positrons, and neutrinos. Gamma rays accompany them. If the initial particle was not energetic enough — and most aren't — the particles stop within the atmosphere, never reaching the surface.

One way to detect high-energy particles on the ground is by a secondary radiation effect called Cerenkov radiation. When light travels through anything outside a vacuum, its speed slows, but high-energy particles don't slow as much. As these high-energy particles travel through water or the atmosphere, they move faster than the speed of light in that medium and generate an "optical shock wave." This is similar to a sonic boom created by fast-moving aircraft.

Cerenkov radiation appears as a cone of ultraviolet and blue light — visible to any optical detector as a flash of blue light.

Shuttle, ISS, and Apollo astronauts all have reported seeing flashes of light when they are in complete darkness or when they close their eyes. These flashes occur because a gel-like substance — called the vitreous humor — fills roughly 80 percent of the eye. Because the vitreous humor is composed mostly of water, the astronauts' eyes acted as Cerenkov-radiation detectors. The optical shock wave moved through the vitreous humor, and their retinas detected these light flashes. — *L. K.*



AN INCOMING high-energy particle will not slow as much as light does when entering the vitreous humor. This creates an optical shock wave. A cone of blue light lands on the retina, causing the observer to see a flash.

A TANK filled with pure water makes a great Cerenkov-radiation detector. One example is the Pierre Auger cosmic-ray experiment in which 1,600 tanks, each filled with 3,000 gallons of water, cover roughly the area of Rhode Island. Each tank has three photomultiplier tubes (PMTs) to detect the light. The high-energy particle easily passes through the tank cover, creating an optical shock wave in the water. This light bounces off the reflective interior and is detected by the PMTs. From the detected energy, scientists infer the incoming particle's energy.

cataracts, radiation sickness, damage to the central nervous and immune systems, and, possibly, heart disease.

Some people are more susceptible to radiation than others. Older people are at a lower risk, because cancers have less time to develop. In general, cancer kills more men than women.

Radiation affects human cells at the molecular level. DNA, the basic building block of life, is contained in every cell in our body. As ionizing radiation surges through living tissue, it can sever DNA strands.

Low radiation doses over a prolonged time may be manageable — the body has time to repair the damage. But in a high dose — for example, from an intense solar flare — the effect can be more serious. Cells may be changed permanently and produce cancerous cells. This effect is difficult to measure. Decades might pass between the radiation exposure and the appearance of a tumor. In the extreme case, cell damage stops body tissues from working, and radiation sickness — or even death — results.

Scientists are developing dietary supplements and drugs to protect astronauts from these damaging biological effects, with an emphasis on preventing cancer. As radiation specialist Zeitlin says, "No matter how well we design the shielding, particles are going to come through, and astronauts will get a much larger radiation dose than we get on Earth. That will increase their risk of cancer and other illnesses, so it would be extremely useful to find a drug or a dietary supplement, or some combination of the two, that helps keep those risks down."

Astronauts who travel outside the protective boundaries of our planet will encounter high doses of damaging radiation. In fact, astronauts have seen blue flashes of light from cosmic rays zipping through their eyes (see "Eye-opening experience" above), and many former astronauts have cataracts.

Years ago, scientists didn't fully understand space radiation, and while they know more now, it's not enough to send astronauts on a 3-year mission safely. We must learn the long-term effects of space travel on the human body, and how to protect voyagers, before we can boldly and safely go where no one has gone before.

ONLINE EXTRA What does radiation *really* do to the human body? Find out at www.astronomy.com/toc.

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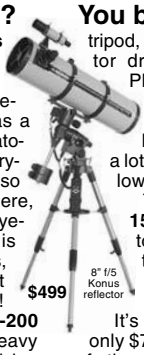

$499
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> The weather finally cleared here last weekend and I got to put the Celestron CPC 8 that I just purchased to the test. I'm from the "old" school of star hopping and manual setting circles. This was my first time with a computerized telescope.
>
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> It is a truly amazing process. Every time I told the scope to go find something, it did so with dead-on accuracy. Doing it the old fashioned way would have taken me far longer. I'm sold on SkyAlign. I'm still amazed how it can put objects dead center in the middle of the field of view.
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The **Astro-Tech AT80** has dual speed focusing – one knob for standard speed focusing, the other for ultra-fine focusing at an 11:1 ratio. It comes with a fully rotatable 2" Crayford-style focuser and 1.25" eyepiece adapter, both with compression ring eyepiece holders; retractable self-storing lens shade; dust caps; and fitted soft carrying case. Use it as a super finder or photoguide for your main scope or as an optically excellent second scope for spur-of-the-moment astronomy, travel, or birding. Available in white and Meade blue.

$299 for a Meade Deep Sky Imager.

The **Meade Deep Sky Imager** takes full color photos of galaxies, nebulas, star clusters, the Moon, and planets at a fraction the cost of a CCD camera.

The DSI is a one-pass color camera, so there's no need to take multiple exposures through filters and combine them later to come up with a color image.

The easy-to-use Meade Deep Sky Imager also includes a USB cable and the Autostar Software Suite of imaging control software in its low price of only $299.

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What makes this **Meade ETX-80AT** 3.1" go-to refractor such a good deal for only $279.99?

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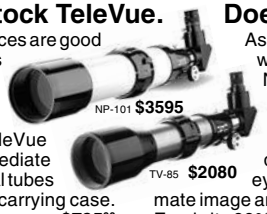


If it's from TeleVue, chances are good we have it in stock. Others say they carry TeleVue, *but we actually keep TeleVue in stock.* Lots of it.

Here are a few of the TeleVue scopes we stock for immediate shipment. These are optical tubes only, with dust covers and carrying case.

TV-60, 2.4" f/6 apo	**$795.00**
TV-76, 3" f/6.3 apo	**1275.00**
TV-85, 3.35" f/7 apo	**1680.00**
TV-102, 4" f/8.6 apo	**2200.00**

The following scope packages (for use on your own mount) with a star diagonal, Plössl eyepiece, tube ring, dust covers, and case, are also in stock.

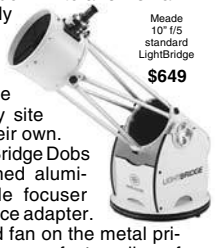
TV-76, 3" f/6.3 apo	**$1675.00**
TV-85, 3.35" f/7 apo	**2080.00**
TV-102, 4" f/8.6 apo	**2635.00**
Renaissance, 4" f/8.6 brass	**2935.00**
NP-101, 4" f/5.4 Petzval apo	**3595.00**

Does your dealer?

As for TeleVue accessories, we have them all in stock. Need a Gibraltar, TelePod, or Panoramic altazimuth mount? A Sky Tour computer? Need a Nagler, Radian, Panoptic, or Plössl eyepiece? Need a Powermate image amplifier or a Barlow lens; an Everbrite 99% reflectivity star diagonal; a light pollution filter; one of the Dioptrx astigmatism-correcting lens? A BinoVue? No matter. If it's from TeleVue, chances are good we have it in stock. For example, here are a few of the eyepieces from TeleVue that we can ship today.

2-4mm 1.25" Nagler zoom	**$395.00**
3-6mm 1.25" Nagler zoom	**380.00**
2.5mm 1.25" Nagler Type 6	**280.00**
3.5mm 1.25" Nagler Type 6	**280.00**
20mm 2" Nagler Type 5	**440.00**
31mm 2" Nagler Type 5	**620.00**

Outer space is infinite. Your car's back seat is not.



Meade LightBridge Dobsonians use a truss-tube design that lets even the big 12" models break down into a few small packages that easily fit into a compact car. One person can transport a Meade LightBridge Dob to a dark sky site and set it up on their own.

All Meade LightBridge Dobs have a 2" machined aluminum Crayford-style focuser with a 1.25" eyepiece adapter. A battery-operated fan on the metal primary mirror cell assures fast cooling of the diffraction-limited BK7 optical glass mirror. No tools are needed to assemble and break down the scope in the field.

Standard models have a 1.25" 26mm Super Plössl eyepiece, a red dot finder, and Teflon bearings. Deluxe models have a 2" 26mm 70° field QX eyepiece, an illuminated finder with four different reticle patterns, and roller bearings for smooth hitch-free motion at the touch of a finger.

The prices below include the shipping from the Meade factory.

8" f/6	standard LightBridge	**$469.00**
8" f/6	deluxe LightBridge	**569.00**
10" f/5	standard LightBridge	**649.00**
10" f/5	deluxe LightBridge	**749.00**
12" f/5	standard LightBridge	**949.00**
12" f/5	deluxe LightBridge	**1049.00**

UWAN an 82° field eyepiece for $198? You got it.

The **William Optics** 4, 7, and 16mm 1.25" UWAN eyepieces, and the 2" 28mm, all have very wide 82° fields – starting at only $198 each. That's lower than many competitive 82° (or even 70° field) eyepieces.

The right accessories make your observing easier.

A red flashlight protects your dark-adapted night vision while you observe. **Celestron's** variable brightness red flashlight, our part #VLED, costs **$19.95**.

The **Rigel Systems** continuously variable brightness dual red LED flashlight shown to the right, our part #4591, is **$24.95**.

Rigel's very handy two-color variable brightness light (#4592) – dual red LEDs for reading star charts, dual blue-white LEDs for setting up or taking down your scope – is only **$29.95**.

Vibration suppression pads under the legs of your telescope tripod virtually end the tremors that blur your view for a few seconds every time a breeze comes up or you touch the scope to focus.

A set of three **Celestron** anti-vibration pads, our part #VSP, costs **$49.50.**

The **Meade** #895 set of three anti-vibration pads shown to the right costs **$49.95.**

Either set takes the constant vibration and frustration out of observing and are well worth their low cost.

The **Celestron Power Tank** rechargeable 12-volt batteries have the power you need to run your telescope and accessories all night long. You can recharge them hundreds of times, saving youhundreds of dollars over the cost of buying new flashlight batteries every few weeks. Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; a built-in recharger; shoulder strap; carry handle; and more.

The 7 amp hour capacity Power Tank shown above, our part #4512V, is only **$59.95**. The 17 amp hour capacity Power Tank, our #4517V, is only **$89.95**.

Antares 7 x 50mm and 12 x 80mm right angle finders cost from **$79.95** to **$184.95**. Ther're available0 in either size in Celestron black, Meade blue, or gloss white. Choose from standard mirror-image versions or erect right-reading models that show the sky the way it appears on star charts.

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ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: gravity beats the universe's expansion, Hubble's imaging limit, and astrophoto lingo.

GRAVITY'S POWER

Q: If galaxies are moving farther apart, why are there still galactic collisions? — JOSHUA COLBERT, SILVER SPRING, MARYLAND

A: The expanding universe is just the playing field where galaxies interact with each other. The most important way they interact is by gravity, whose range is, theoretically, unlimited. Every galaxy attracts every other galaxy, and their mutual pull slows the rate of moving apart from each other. **The closer two galaxies are to each other, the stronger their gravitational attraction is (and the slower the pace at which expansion would tear them apart).**

This doesn't make much of a difference on large scales, where the universe looks essentially the same everywhere, and every galaxy "feels" a similar pull in every direction. Locally, though, gravity may overwhelm cosmic expansion and pull two or more nearby galaxies that were initially moving apart together again.

While it is true, on average and over large distances, that galaxies are moving apart, it is not true for every galaxy and on small scales. Our Milky Way and the Andromeda Galaxy, for example, have been approaching each other for billions of years. Satellite galaxies, like the Magellanic Clouds orbiting the Milky Way, are not carried away by the expansion either.

Likewise, other galaxy groups — such as the Virgo cluster — are not expanding because gravity has stopped the expansion locally. The Hubble Flow, the general motion of galaxies away from each other, is not uniform but permeated by eddies, currents, streams, and pools, as galaxies tug on each other via gravity.

Why then are there galaxies that have not collided? Usually, galaxies that have pulled each other out of the Hubble Flow will not immediately smash into each other because galaxies are small targets to hit in a large universe. Rather, they form a group or small cluster — gatherings of dozens, hundreds, sometimes thousands of galaxies — held together by gravity just like the solar system is held together by the Sun's gravity.

Galaxies roam across the field and within groups and clusters in a disorganized way, and collisions are prone to happen. But because galaxies are small compared to the space they live in, major mergers — collisions between two equal-size galaxies that shake them up completely — don't happen

NASA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

TWO SPIRAL GALAXIES, NGC 2207 (left) and IC 2163, are trapped by each other's gravitational pull. For billions of years, they will continue to distort each other, flinging stars and dust, until they eventually merge into a massive galaxy.

frequently. A galaxy that has joined a group or cluster can live there comfortably without ever passing dangerously close to another galaxy for billions of years.

Only a minor fraction of the Milky-Way-like galaxies that we see around us today are thought to have suffered a major collision during the past few billion years. It is a matter of time and chance, and it is an ongoing process. Galaxies, groups, and clusters continue to grow by pulling in other galaxies, groups, and clusters. The universe is still under construction today.

Of all these environments, though, a group is the most dangerous place for a galaxy to live. Galaxies that live out in the field — probably a minority of such objects — are so solitary that they seldom cross other galaxies' paths. And while clusters are crowded, the galaxies in them move at such frantic speeds that, even when they do encounter each other, they simply race past without any ill effects.

But in groups, galaxies move at a moderate pace, similar to the speeds of their own stars in their orbits. This makes it more likely that the galaxies will not only encounter each other occasionally, but also will feel their mutual gravitational pull strongly and for a prolonged time. Thus, groups of galaxies, and not big clusters, are the most likely places where the histories of galaxies are written. — **DANIEL CHRISTLEIN,** UNIVERSIDAD DE CHILE AND YALE UNIVERSITY

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187.
Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

IN THE KNOW

CCD LUMINANCE (L) IMAGING
Usually a long, unfiltered exposure; in a CCD image, luminance data (when taken) represents the bulk of the total exposure; this allows the chrominance (R, G, and B) images to be short; luminance is an object's brightness factor.

HUBBLE'S LIMIT

Q: How can the Hubble Space Telescope (HST) take pictures of objects light-years away but not get a good picture of Pluto? — **BRENT KASPER,** MADISON, INDIANA

A: Pluto is very small. At its distance, **it subtends a smaller angle on the sky than does a galaxy** at a distance of billions of light-years. Consequently, even HST cannot resolve the planet's surface very well, because that would require a resolution of better than about 0.1". Still, HST has produced a spectacular image of Pluto and its moon Charon. — **MARIO LIVIO,** SPACE TELESCOPE SCIENCE INSTITUTE, BALTIMORE

COMBINING ASTROPHOTOS

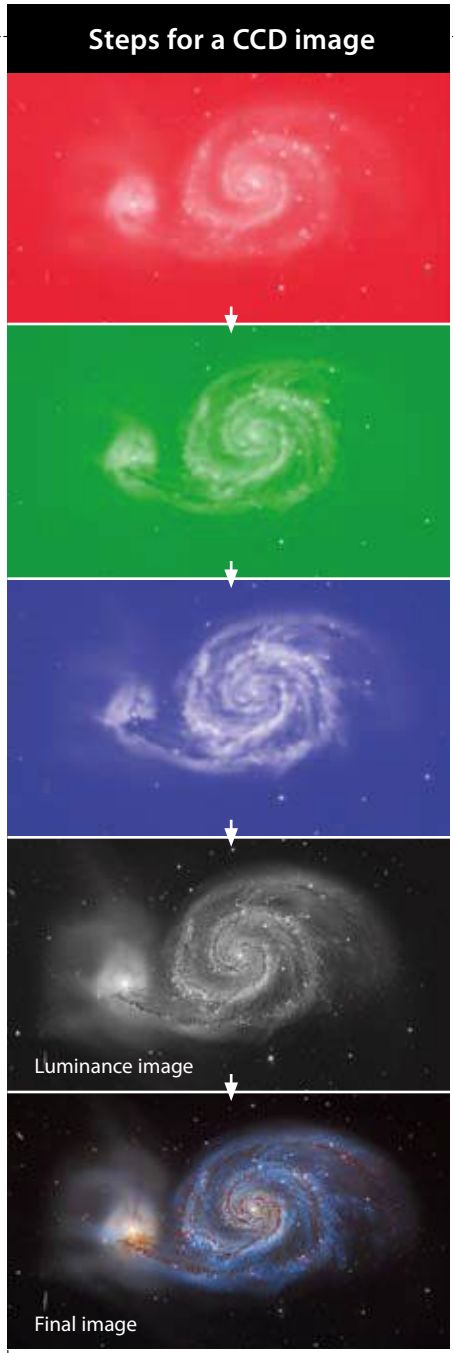
Q: Almost all "Reader gallery" pictures seem to be four or more long exposures. Are these pictures combined, and if so, how? — **DIANE WOOD,** EVANSVILLE, INDIANA

A: Yes, and in "Reader gallery" captions, we list the type of image and what exposures the imager combined to arrive at the final picture. Take, for example, "LRGB image with exposures of 80, 20, 20, and 30 minutes, respectively." The published image contains 4 exposures: an 80-minute unfiltered luminance (L) image, 20-minute photos through red (R) and green (G) filters, and a 30-minute exposure through a blue (B) filter.

Depending on which filters you use, only light associated with specific wavelengths — red, green, blue, or even infrared — will hit the photographic plate. **When you add the images together, associating each filtered image with either R, G, or B, you get a full-color image.**

Some imagers use small, modified video cameras — or webcams — to acquire data. So a caption that reads "best 50 of 600 images" means the imager used software to select the best 50 images out of a continuous batch of 600 obtained with a webcam. One frame differs from another in clarity because our atmosphere is in constant motion.

For LRGB (and similar) images, each exposure is saved as a separate file that software such as Adobe *Photoshop* can interpret. Software such as *Registax* combines multiple webcam exposures into a final image. Each imager has his or her own way of processing exposures to highlight different aspects of the photographed object. — **MICHAEL E. BAKICH,** PHOTO EDITOR



TO CREATE a multicolor astrophoto, combine CCD images taken through red (R), green (G), and blue (B) filters. If you add a luminance (L) image to the combined RGB image, your final product will be stunning.

One special night can show you the northern sky's 109 best objects.

/// BY MICHAEL E. BAKICH

Take a deep-sky treasure hunt

Most observers recognize the Messier catalog, which contains the *crème de la crème* of deep-sky objects. But did you know you can see them all in 1 night? As Northern Hemisphere spring brings warmer weather, a window of opportunity opens and beckons you to observe.

The catalog

French astronomer Charles Messier (1730–1817) was a comet-hunter. In his searches, he occasionally encountered celestial objects that resembled comets — they appeared fuzzy in his small telescope — but did not move against the background of stars. This last trait eliminated the possibility they were comets.

Eighteenth-century astronomers called these objects nebulae, a word whose definition is more specific today. Messier, however, was concerned other observers would report these faint fuzzies as comets, so he compiled them into a catalog of 109 objects: open and globular star clusters, normal and planetary nebulae, and galaxies.

During a comet search August 28, 1758, Messier discovered a misty patch in Taurus. This was the first of his non-moving objects, and it later became the initial entry — M1 — in his catalog. Messier published three versions of this catalog. The first, in 1769, contained 45 objects either he discovered or other observers reported to him, and which he confirmed. The second version, with 68 objects, appeared in 1780. The third, containing 103 objects, appeared the following year. Later discoveries by Messier and others brought the final tally of objects to 109, the catalog we recognize today.

Messier discovered 41 of the 109 objects on the current list, the most of any discoverer. French astronomer Pierre Méchain (1744–1804) ranks second with 27. In addition, Messier discovered 13 comets and made 7 independent codiscoveries.

Because Messier's telescope was small, he could find only large, bright objects. Through modern scopes, which are larger than Messier's and possess higher-quality optics, each is a showpiece. Individually, the Messier objects rank as the brightest and finest northern deep-sky targets.

Running the marathon

Messier's 109 objects are not distributed evenly across the sky. Sagittarius, for example, holds 15 of them, the greatest number in any constellation. Virgo is next (11), followed by Coma Berenices (eight), and Ophiuchus and Ursa Major (seven each). Add to this distribution the fact that no M object resides in western Aquarius or eastern Pisces. So when the Sun passes that area in its yearly apparent trip through the zodiac, it sits farthest from any M object, and a chance exists for observers to see them all in 1 night.

The first extended mention of the Messier marathon as an event appeared in an article by American geodesist Brent Archinal published in the March 1982 issue of *Deep Sky Monthly* magazine.

Michael E. Bakich *is an associate editor of* Astronomy.

REFLECTION NEBULA M78 in Orion glows at 8th magnitude. Don't use a nebula filter to observe this object, however, because M78's light is reflected and scattered starlight, much of which is blocked by such filters.

JOHN CHUMACK

THE OMEGA NEBULA (M17) in Sagittarius, a bright emission nebula, looks even better through an OIII or other nebula filter. MARK HANSON

TEN TIPS FOR A MESSIER MARATHON

1 Connect with a local astronomy club. If you do this, the rest of the list probably will be taken care of by others. Don't be shy about asking other, more experienced observers for help.

2 Choose a dark site with a low horizon. Remember, a few of the objects (M74 and M30) will be low when you observe them.

3 Bring a good star atlas. Know its layout before the marathon. Some observers make a separate page noting which Messier objects appear on each map.

4 Review your observing plan before you head out. For an online planning guide, visit www.astronomy.com/toc.

5 Bring warm clothes, and dress in layers. It may be spring, but you won't be running a marathon. Instead, you'll be standing, sitting, looking, and talking. You will get cold.

6 Bring and use only a red flashlight, preferably a dimmable one. White light — in fact, bright light of any color — harms observers' night vision.

7 Bring a comfortable observing chair, and use it. You'll be out all night, and standing that long isn't an option.

ALAN DYER

READY, SET, OBSERVE! Astronomy clubs around the world host Messier marathons.

8 Keep a record (log) of the Messier objects you observe throughout the night. Your log can have lots of details: time, telescope, eyepiece/magnification, even sketches. Alternately, you can use a simple checklist.

9 Don't get frustrated when searching for galaxies in Virgo. It's not that you won't be able to see them; rather, you'll see more than just the M objects. Take your time, and check your star chart often.

10 Check your telescope and accessories at home. Even if this means setting up in your living room, you'll solve problems more easily at home than in the dark. — *M. E. B.*

NAKED-EYE MARATHON

Some observers want an even bigger challenge than a binocular Messier marathon. Here's one: Try to see 20 or more Messier objects with your unaided eyes. A few, like the Pleiades (M45), represent no challenge. Others, like Bode's Galaxy (M81), require a star chart to find.

Brian Skiff, at Lowell Observatory in Flagstaff, Arizona, maintains a working list of naked-eye, deep-sky objects seen by him or reported to him by reputable observers. As of November 1, 2005, the following Messier objects had been spotted with the naked eye:

M2, M3, M4, M5, M6, M7, M8, M11, M13, M15, M16, M17, M20, M22, M23, M24, M25, M31, M33, M34, M35, M36, M37, M38, M39, M41, M42, M44, M45, M46, M47, M48, M50, M67, M81, and M93.

Skiff also notes that observers have reported probable naked-eye sightings of M83 and M92.
— *M. E. B.*

SPIRAL GALAXY M101 should appear bright at magnitude 7.9. Don't expect a dazzling sight, however, because M101 has a low surface brightness. DANIEL B. PHILLIPS

SPIRAL GALAXY M88 in Coma Berenices presents no problem for Messier hunters using a 4-inch or larger telescope from a dark site. To see its tightly wound spiral arms, however, you'll need at least a 12-inch scope. BOB FERA

I have participated in Messier marathons since the early 1970s. My first 100+ marathon occurred March 23/24, 1974, from a location near the Ohio State University campus in Columbus. A friend and I logged 105 Messier objects using his 6-inch Newtonian reflector. I've seen all 109 Messier objects in one night through a variety of instruments since then, and so can you.

Possible marathon dates

Contributing editor Tom Polakis has calculated the window of opportunity for a complete Messier marathon. The beginning of the observing window is defined by the date when globular cluster M30 in Capricornus is high enough to see in a dark sky. Working with the premise that the object has to be at an altitude of 2° to be seen, Polakis calculated the Sun's altitude at that time and its distance from M30. On the evening end, the limiting object is spiral galaxy M74 in Pisces. The inability to see it through twilight's glare defines the end of the window of observing dates.

Polakis' numbers are for 33° north latitude, and they get more favorable the more southerly your observing site, particularly for M30. So the season begins about March 17. Using the same criterion for the evening view of M74, it ends April 3.

Can you see them all?

The quick answer is "yes." Many people have viewed all the Messier objects during a single night. The challenge for some observers comes from trying to see as many as possible in as small a telescope (or binoculars) as possible. With a high-quality 3-inch telescope, all the Messier objects can be seen from a dark site on a good night. Archinal saw all 109 with 11x70 binoculars March 24/25, 2000.

I once tried a Messier marathon with 7x50 binoculars. Unfortunately, the night was miserable. On March 4/5, 2000, the sky was partly cloudy, and the seeing (sky steadiness) ranked 7 out of 10. I rated the transparency (sky darkness) only 4 out of 10. Even under such poor conditions, I saw 75 M objects, and I believe spotting 90 with good 7x50 binoculars is a strong possibility.

Turn south at M33

You can find a Messier marathon planning guide online at www.astronomy.com/toc. Other resources exist that suggest a search order for the Messier objects during a marathon. Most have been compiled with upper northerly latitudes in mind. If you live in Europe or in the northern part of the United States, such lists should work fine. However, for the southern states, the sequence may be off somewhat. Southerly M objects rise earlier than indicated by most marathon lists. The best procedure is to use a planetarium charting program such as Software Bisque's *TheSky* to compile a custom Messier marathon sequence based on your latitude.

Why marathon?

After more than 30 years of Messier marathons, there's one approach I've never tried: doing it alone. To guarantee you'll enjoy the marathon, make it a social event. Every astronomy club with a dedicated cadre of observers schedules a Messier marathon. Hard-core amateurs hold it as close to New Moon as possible, whenever that falls. Most clubs, however, schedule their marathon for the Saturday night nearest New Moon.

For example, this year New Moon in March falls on Wednesday the 29th. Ideally, we'd all go out that night and see the entire list of 109 objects. Many of us, however,

THE LITTLE STAR CLOUD (M24) in Sagittarius lies in a densely concentrated region of the Milky Way. JASON WARE

must work the next day, so our best options become either the preceding Saturday, March 25, or the following Saturday, April 1. Because March 25 is closer to the center of the marathon window, I suggest you aim for that date, and keep April 1 (no fooling!) as your "bad weather" backup date.

Above all, a Messier marathon is fun, not hard science. It's a time when observers come together with a common purpose. As a bonus, a night under the stars with a group of amateur astronomers lets you check out new telescopes and accessories. And what if you don't see all the Messier objects? Well, my calculations indicate the New Moon in the 2007 marathon window falls Sunday, March 18. Good luck!

ONLINE EXTRA For a step-by-step guide through the Messier marathon, log on to www.astronomy.com/toc.

GLOBULAR CLUSTER M92 in Hercules would be better known if it weren't in the same constellation as an even brighter globular — the Hercules Cluster (M13). M92, which shines at magnitude 6.4, looks great at high magnification. BOB FERA

Central California's astronomical brain trust boasts imagers, inventors, and manufacturers. /// BY TONY HALLAS

The fabulous foothill gang

The discovery of gold in California's Sierra foothills 150

years ago attracted searchers of fortune. The gold fever is gone, but the spirit of discovery is still alive. Halfway between Sacramento and Lake Tahoe lives the fabulous foothill gang, a group of people mining the celestial gold of dark skies and clear air. ☾ The foothill gang is an informal organization with no dues or membership. It's a group of like-minded astronomy

ALL PHOTOS THIS PAGE: TONY HALLAS

gurus who find themselves living in the same geographic area.

The gang members are an eclectic crew — Larry Myers builds go-to telescope mounts; Don Machholz hunts comets and has made 10 discoveries; Tom Osypowski makes equatorial platforms for Dobsonian-mounted scopes; I am a CCD imager; Wayne Brown fabricates imaging chips for CCD cameras; Don Goldman produces astronomical filters; Bob Fera collects photons from distant astronomical objects; Jim Wray constructs professional telescopes and their domes; Ken Crawford pursues narrowband imaging; and Vic Maris builds high-quality refractors.

Tony Hallas *is a self-taught California astrophotographer who has captured the beauty of celestial objects since 1987.*

Larry Myers — telescope mounts

Larry Myers owns Mountain Instruments, which produces the MI-250 go-to mount. Myers' grandparents sparked his interest in astronomy: His grandfather saw Halley's Comet twice.

Myers studied chemical engineering in college but never lost interest in astronomy. A few years after college, he took a metal-working class and built a telescope mount.

THE CRESCENT NEBULA (NGC 6888) in Cygnus is a cosmic bubble created by an intensely hot star. Don Goldman took this image through Astrodon Hydrogen-alpha, Oxygen III, and Silicon II filters.

TONY HALLAS

LARRY MYERS owns Mountain Instruments, which produces the MI-250 go-to telescope mount, seen here in various stages of construction.

TONY HALLAS

DON MACHHOLZ'S interest in astronomy started when he was 8 years old. Since then, he's discovered 10 comets. During the summer, Machholz organizes public star parties.

TONY HALLAS

TOM OSYPOWSKI, owner of Equatorial Platforms, doesn't build telescopes — he makes them track better. Osypowski constructs motorized platforms for reflectors on Dobsonian-mounts. The platforms allow observers to view or image celestial objects without having to move the telescope continually.

After becoming a proficient astrophotographer and authoring several published articles, Myers realized solid, portable mounts were necessary for imaging, and he started building them in his garage. As demand for his mounts grew, he gave up his chemical-engineering job to build telescope mounts full-time.

The MI-250 go-to mount resulted from years of refinement and innovation. No other mount boasts such rigidity for its size. Each is painstakingly assembled, and each right ascension worm-and-gear assembly is lapped as a matched set, which assures smooth tracking. Coupled with Losmandy Gemini electronics, the mount achieves a pointing accuracy that will put a celestial object smack in the middle of a CCD chip. At last count, more than 400 MI-250 mounts were in use, and the number is increasing rapidly.

Don Machholz — ice-ball hunter

Close to Myers lives comet-hunter Don Machholz. Every clear morning, Machholz rises before dawn to scan the eastern sky in search of his elusive prey. He discovered several comets from his foothill observatory. This was an amazing achievement given the professional automated CCD sky surveys that run constantly. Machholz has discovered 10 comets, but he says it's getting harder due to projects looking for objects with near-Earth trajectories.

Machholz's interest in astronomy started when he was 8. He wanted to know what he was looking at in the sky, so he borrowed his dad's Navy navigational maps. He tried black-and-white astrophotography but decided comet-hunting was his true calling.

Machholz is generous with his knowledge — during the summer, he organizes public star parties. As a reflection of his pioneering spirit, Machholz builds much of the equipment he uses to search for comets.

Tom Osypowski — stable Dobsonian platforms

A short drive north, down a dirt road through a stand of pine trees, is the home of Tom Osypowski, owner of Equatorial Platforms. Osypowski's love affair with the night sky began at the age of 12, when he made his first telescope.

Later in life, he became a master woodcraftsman. Frustrated that his Dobsonian-mounted telescope couldn't track, Osypowski did some research and built his first equatorial platform, which moved the scope and kept it pointing to the same place. His commercial platforms appeared in 1984, and he has constantly improved them ever since. They culminated in today's lightweight, sturdy devices made either of wood or aluminum.

Osypowski is a superb telescope-maker. Several years ago, he introduced his "Spica Eyes" line, named for his cat who can see objects clearly in the dark. These exquisite Dobsonian-mounted scopes are made from aluminum. He constructed his largest to date — a 28-inch giant — for mirror-maker Steve Kennedy. Osypowski uses a 24-inch f/3.66 with razor-sharp optics. It splits Antares into two distinct, brilliant dots — one bright orange, the other blue. Any clear

FACE-ON spiral galaxy NGC 6946 in Cepheus shines at magnitude 8.9, but its surface brightness is low because it's so large. Tony Hallas needed 9 hours 45 minutes of total exposure time through a 14.5-inch classical Cassegrain reflector to produce this image.

night will find him outside his shop gathering distant photons.

Tony Hallas — CCD extremist

South of Osypowski's house, as the crow flies, lies American River's north fork, near Foresthill, where I live. Fed up with the light-polluted skies of southern California and increasing air pollution, my wife

VAN DEN BERGH 141 in Cepheus is difficult to observe visually. This image, however, shows it well. Bob and Janice Fera snagged Van den Bergh 141 through their 12.5-inch Parallax Instruments Ritchey-Chrétien reflector with an SBIG ST-10XE CCD camera. The final LRGB image combined four exposures totaling 6 hours.

DAPHNE HALLAS

TONY HALLAS acquires many of his images through a 6-inch f/7.9 Stellarvue SV152 refractor. Hallas moved to Foresthill, California, for the dark, open sky.

TONY HALLAS

BOB AND JANICE FERA moved to the foothill area for convenience. Rather than spend hours on the highway to and from Mount Pinos (an imagers' Mecca), Fera now shoots from his backyard.

JIM WRAY, telescope-builder and author, stands with the 24-inch Cassegrain reflector he constructed. The telescope will be installed on Palomar Mountain and will be used to study the newly discovered 10th planet.

TONY HALLAS

TONY HALLAS

WAYNE BROWN founded Apogee Instruments in the 1990s. In addition to astronomical uses, Apogee supplies CCD cameras for biotech and forensic sciences.

Daphne and I made the decision in 1998 to move. During a conversation with Larry Myers at the Riverside Telescope Makers Conference, he said, "Why don't you guys come up to where I live and take a look?"

One look was all it took. We were fortunate to find a piece of property in a community of 30 home sites with an open sky; trees surround most lots in the Sierra. Now, for the first time, I have a backyard observatory. The first negative I exposed from here made me think the film was dead. It wasn't until I looked at the negative under magnification that I realized the object was there — just no sky fog!

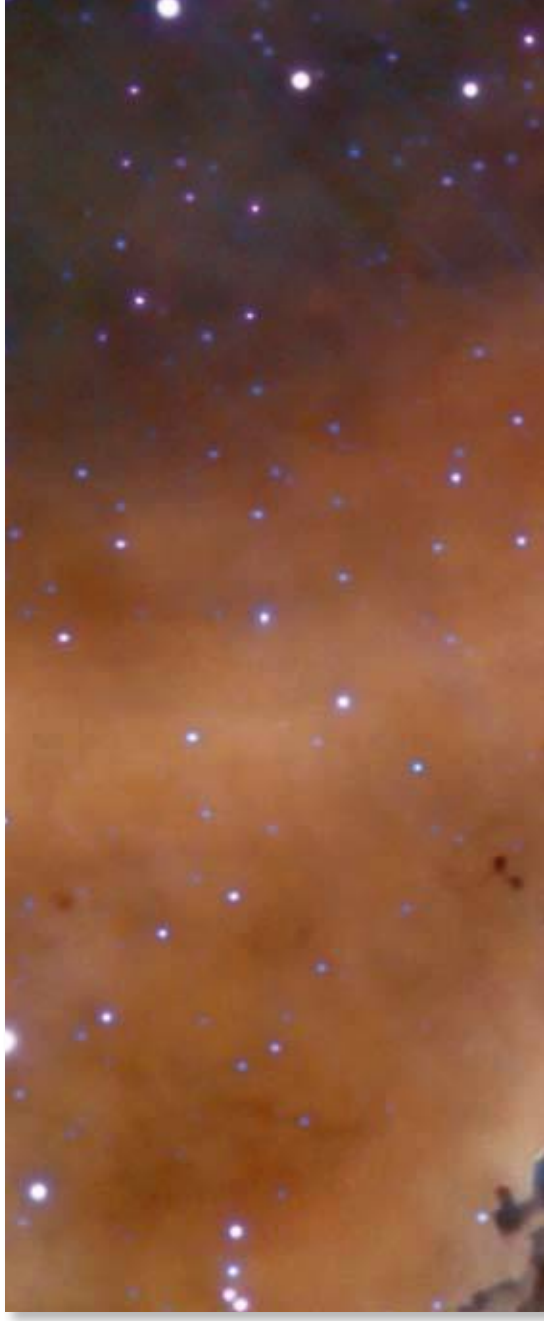
As I progressed to CCD imaging, I found the dark sky to be equally beneficial for images that push the limit of amateur astrophotography. After hauling heavy equipment to remote observing sites all those years, I feel a bit spoiled having a dark sky and an observatory only seconds from my door.

Currently, I'm imaging some of the large objects I shot years ago on 6x7 film. I'm using a 6-inch f/8 Stellarvue fluorite air-spaced triplet with a two-element field flattener connected to an SBIG STL-11K CCD camera. My first project is to reshoot the Andromeda Galaxy (M31). In my first images, I discovered a tidal warp at the galaxy's ends and faint stars going far beyond the usual boundaries.

My other telescope is a 14.5-inch f/8 RC Optical Systems classical Cassegrain with Tom Scott optics. Images I acquired through this telescope showed the expanding shell of the Ring Nebula (M57) and the explosive outbursts from the Cigar Galaxy (M82) better than I'd seen anywhere else.

Bob and Janice Fera — astrophotographers

Minutes from my house live Bob and Janice Fera, longtime members of the famous Mount Pinos Rat Pack, a group of several hundred amateur astronomers that meets in the Mount Pinos parking lot — 2 hours north of Los Angeles and 8,300 feet (2,530 meters) above sea level — to observe and image. After a visit to our neck of the woods, they decided to move here as well. Fera is an accomplished astrophotographer who has had many images published. He now enjoys shooting from his own observatory. Fera images with a 12.5-inch Parallax Instruments Ritchey-Chrétien reflector on an Astro-Physics 1200GTO mount.



Jim Wray — big-scope builder

Foresthill is also home to one of the great minds in astronomy today, James Wray. "Jim," as he is known to his friends, is a master telescope-builder and constructs professional telescopes single-handedly, including their automated domes.

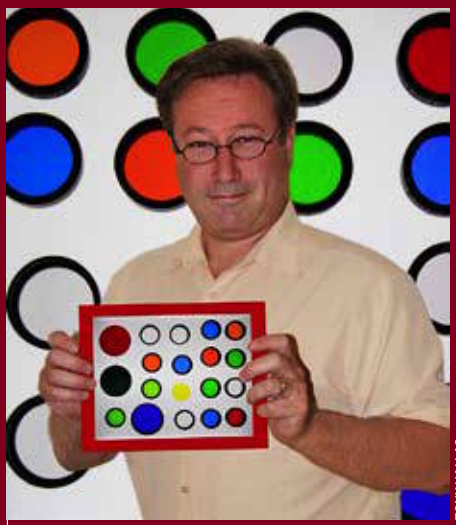
Wray's latest project is a 24-inch Cassegrain reflector to be installed on Palomar Mountain that will be used by Caltech astronomers for further study of the tenth planet. Wray also has published an important book, *The Color Atlas of Galaxies*, which is filled with photographs taken with ultraviolet (U), blue (B), and violet (V) filters. Using filters at the blue end of the spectrum, Wray recorded the stellar components of galaxies without the interference of reddish nebulae.

THE ROSETTE NEBULA (NGC 2237–9) in Monoceros doesn't look as rosy when imaged through Hydrogen-alpha, Oxygen III, and Silicon II filters. Ken Crawford shot this image through a 20-inch RC Optical Systems Ritchey-Chrétien reflector using an SBIG ST-10XME CCD camera.

Wayne Brown — CCD maker

West of Foresthill, at the base of the foothills, lies Apogee Instruments, Inc. Astronomers use Apogee's state-of-the-art back-illuminated CCD cameras. Only a small portion of Apogee's clients are astronomical, however. Companies use this equipment for biotechnology, microscopy, luminance, laser, and forensic sciences.

BARRED SPIRAL GALAXY NGC 4725 in Coma Berenices lies 40 million light-years away. Bob and Janice Fera took this image through a 12.5-inch Parallax Instruments Ritchey-Chrétien reflector at f/9 with an SBIG ST-10XE CCD camera. The final LRGB image combined unfiltered, red, green, and blue exposures of 150, 60, 60, and 60 minutes, respectively, all through Astrodon filters.



TONY HALLAS

DON GOLDMAN founded Astrodon Filters in 2004. By adjusting transmission to match CCD-chip sensitivity, Astrodon filters allow CCD imagers to shoot equal-time red, green, and blue exposures.

TONY HALLAS

KEN CRAWFORD images with a 20-inch RC Optical Systems Ritchey-Chrétien reflector, but how he images is the real story. Crawford uses Hydrogen-alpha, Oxygen III, and Silicon II filters to produce new views of familiar celestial objects.

TONY HALLAS

VIC MARIS was a park ranger and naturalist for 30 years before founding Stellarvue Telescopes. Stellarvue produces high-quality refractors from 3.2 inches to 6 inches in aperture.

That may change with the release of a compact, affordable CCD camera called the Ascent, to be available early in 2006. The Ascent will feature interline CCD chips in sizes up to 11 megapixels with true USB 2.0 connectivity. This will make downloading images fast — a full download will take less than 2 seconds. The camera also will be lightweight, putting less stress on telescopes and mounts.

Wayne Brown founded Apogee Instruments. Brown began his love affair with astronomy in 1991, when he ground his first telescope mirror. Not liking any of the CCD cameras then available, he proceeded to build his own, developing, along the way, expertise in mechanics, optics, thermal, analog, digital, and software interface technology. He went to work for Lockheed in Bethesda, Maryland. During this time, he worked on the Hubble Space Telescope and other NASA projects.

After moving to Tucson, he continued to work on his CCD camera design and made his first sale. The culmination of his efforts are the high-performance Alta U47 and U42 CCD camera systems, which support 30 different types of CCD chips.

Don Goldman — filtered view

A little farther west, almost too far away to be called a foothill resident, lives Don Goldman. Goldman's interest is spectroscopy, and his involvement with filters stems from his interest in astrophotography. His arrival on the astronomy scene is recent — he bought his first telescope in a pawn shop in 2001. It didn't take long for him to realize he needed better equipment. He now images with a 12.5-inch f/9 RC Optical Systems telescope.

In 2004, Goldman started the Astrodon filter company, producing high-quality red, green, and blue filters with 1:1:1 exposure ratios for blue-sensitive CCD chips. Goldman accomplished this by adjusting the spectral response of Astrodon filters to match that of CCD chips. The CCD imaging crowd quickly took notice, and the company has prospered.

Goldman then added narrowband filters (such as Silicon II, Hydrogen-alpha, and Oxygen III) to the Astrodon line. He also built a mechanized off-axis guider for any telescope that utilizes the standard Astro-Physics 2.7" focuser. Goldman, who holds 14 patents, exemplifies the foothill pioneering spirit.

Ken Crawford — shooting in new light

When Don Goldman ventures deeper into the foothills, he often goes to Ken Crawford's house in the little town of Camino. Crawford has progressed steadily and quickly in the art of CCD imaging. Although he is now active in astrophotography, he did not start out that way.

In 1978, he and his wife moved to the foothills near Placerville, where he tried imaging with film but — as he puts it — "failed miserably" due to poor equipment. He turned instead to computers as a hobby. But the astronomy bug that started in 8th grade with a 6-inch telescope kit from

THE IRIS NEBULA (NGC 7023) in Cepheus is a beautiful reflection nebula with a high dust content. Tony Hallas imaged NGC 7023 from his home in Foresthill, California, through a 14.5-inch RC Optical Systems reflector and an SBIG ST-11000 CCD camera. The image's four exposures totaled 280 minutes.

Edmund Scientific would not go away. In 2001, he bought an 11-inch Celestron NexStar and an SBIG 237a CCD camera. Using his knowledge of electronics, he controlled it remotely from his garage.

Crawford progressed through larger and better telescopes, culminating in his present setup, a 20-inch RC Optical Systems Ritchey-Chrétien reflector on a Paramount with a Yankee Robotics Trifid II 6303E camera. Crawford has been instrumental in the development of this camera by providing knowledgeable feedback to the manufacturer. He's fascinated with narrowband imaging, and he produces some of the finest examples of this CCD art form.

Vic Maris — refractors-r-us

Up the hill lies the lovely town of Auburn, home of Vic Maris, the owner and founder of Stellarvue Telescopes. Like so many others, he became interested in astronomy at an early age; by the time he was a teenager, he was building his own telescopes and accessories. Maris worked as a park ranger and naturalist for 30 years. During that time, he lectured about the night sky and taught classes. Six years ago, during one of these classes, his students asked him to make a telescope. He came back with a 3.2-inch f/6 refractor. It performed so well, he immediately got orders for more, and Stellarvue was born.

Stellarvue deals in refractors. Every telescope is individually star-tested and must pass rigorous mechanical tests before being shipped to the customer. Stellarvue's flagship refractor — the 6-inch f/7.9 fluorite triplet — pushes the limits of performance.

The foothill gang continues to evolve: new members, new ideas, new products, new techniques. All work independently and yet create a unified whole bonded by the love of astronomy.

What started in this area 150 years ago as a gold rush has settled down to the rhythm of something more sustainable — the possibility that every new day may bring something special. A

Convenience, low cost, and good optics make for a fine pair of travel scopes.

/// BY PHIL HARRINGTON

Have lens, will travel

How easy a telescope is to set up usually determines how often it will be used. Two small scopes — the MaxKuei 80HD and the Phoenix 80S — make fine traveling companions. With one of these quick-setup scopes, wide-field Milky Way views are only a minute away.

Several trends exist in today's telescope marketplace. One is the inexpensive, short-focal-length refractor. This trend began more than 15 years ago with the introduction of the Orion ShortTube 80. Today, we are seeing the next wave with the introduction of small, mid-price refractors costing between $400 and $600. Some of those upwardly mobile short-tube achromatic refractors include the Vixen 80M, the Stellarvue Nighthawk, and the Zenithstar 80 from William Optics.

Recently, I tested two other tiny titans — the MaxKuei 80HD and Phoenix 80S. Both are manufactured by ODM Engineering, a little-known company in Taiwan. (Unfortunately, as this review was going to press, the North American distributor for these scopes announced it no longer will carry them. *Astronomy* will notify its readers when a new distributor emerges.)

Outwardly, the MaxKuei 80HD and Phoenix 80S look like two completely different telescopes. The MaxKuei features a nicely finished, off-white aluminum tube, while the Phoenix's flat black aluminum tube looks more austere. Inside, however, these telescopes are next of kin. Both feature 3.2-inch (80mm) f/6 achromatic objective lenses, as well as smooth 2" focusers, retractable dew shields, tripod mounting plates, and padded carrying cases. The MaxKuei has a press-on dust cap, while the Phoenix comes with a screw-on dust cap, which I prefer.

A PADDED CARRYING CASE is included with each telescope. Cutouts for the optional star diagonal and eyepieces allow you to carry everything but a tripod in one case.

Available options for both include 45° erect-image and 90° star diagonals and an 8x50 finder scope. One of the diagonals is a must because of the scopes' limited amount of back-focus. The MaxKuei's focuser has 2⅛" of travel, while the Phoenix extends that to 2⅞". Because the 90° diagonal was out of stock when I was testing the scopes, I used the 45° diagonal, which is less suitable for astronomical viewing because you have to bend more. With it in place, all of my eyepieces focused through both scopes with focuser travel to spare.

When I swapped the diagonal and eyepiece for my camera with adapter to try prime-focus photography, however, I could reach focus only through the Phoenix. The MaxKuei needed an extension tube between the telescope and the camera; this caused some vignetting around the corners of the image's field of view.

Each telescope needs a suitable support. The Phoenix weighs 4 pounds and the MaxKuei only 4.5 pounds, so almost any reasonably sturdy photographic tripod or telescope mount will do. For these tests, I used my own CG-5 equatorial mount. Because both scopes are light and small, they set up in about a minute.

The MaxKuei was advertised as an astronomical telescope, and the Phoenix was marketed as a terrestrial spotting scope, but each fills both roles. Overall construction quality is excellent — no plastic here. The fully multicoated objective lenses show an even, greenish glint when studied under a bright light. I detected no evidence of coating irregularities.

Inside, the tubes are flat black. The MaxKuei's tube has six baffles to keep stray light from infiltrating the optical path and

Phil Harrington *is the author of the new observing guidebook* Star Watch*, which is published by John Wiley & Sons.*

▲THE PHOENIX 80S is small but sturdy. It has a retractable dew shield and a tripod mounting plate. The optical-tube assembly weighs only 4 pounds. The 45° diagonal (shown here) is optional. Eyepieces must be purchased elsewhere.

ALL PHOTOS: *ASTRONOMY*: WILLIAM ZUBACK

◀THE MAXKUEI 80HD'S optical-tube assembly weighs 4.5 pounds. Focuser back-travel is 2⅛". The 45° diagonal (shown here) is optional.

washing out the image. The baffles are large enough to do the job but small enough so as not to reduce the telescope's effective aperture. All baffles are made from curved strips of dark-gray, high-density foam, similar to insulation boards found at home-improvement stores.

Although effective, the baffles are not flat black, which might cause some minor contrast issues when the scope is pointed at a bright object. The Phoenix has one baffle ring just behind the objective, although the inside tube wall has a multitude of tiny ridges to muffle stray light.

Both instruments have 2" Crayford-style focusers that work smoothly, but only the MaxKuei's can be rotated in place. To do this, loosen a large lock collar. This feature is handy if the telescope is used on an equatorial mount, which can tilt the focuser's knobs at some pretty odd angles. I found no play in the MaxKuei's focuser, which means collimation (alignment of the optical components) should remain unaffected whenever the focuser is rotated.

Initially, the weight of my 2" eyepiece caused the MaxKuei focuser's drawtube to slip slowly back when I tilted the telescope more than 45°. To prevent this, turn a small setscrew on the focuser's bottom to adjust the roller pressure. The Phoenix's focuser has the same setscrew adjustment.

To star-test each telescope, I aimed at a bright star and defocused the image, first by turning the focuser inward slightly and then turning it outward beyond the focus point. In an ideal telescope, the two images should look identical. Through both scopes, however, I saw a brighter outer ring around the star on one side of focus but not the other. This indicates spherical aberration, which is caused by a minor imperfection in the way the objective focuses light. The MaxKuei's star-test images also showed a small amount of astigmatism, denoted by slightly oval defocused stars. The Phoenix gave no indication of astigmatism.

/// OPTIONS

Use this resource guide to find telescopes similar in size and price to the MaxKuei 80HD and the Phoenix 80S.

DEALER	MODEL	PRICE	PHONE	WEB SITE
Stellarvue	Nighthawk	$499	530.823.7796	www.stellarvue.com
Vixen North America	80M	$499	845.469.8660	www.vixenamerica.com
William Optics	ZenithStar	$499	866.918.6888	www.williamoptics.com

THE OPTICS of the Phoenix 80S and the MaxKuei 80HD are the same. Each telescope is a 3.2-inch (80mm) f/6 achromatic refractor ideally suited for travel and quick setup.

To test both telescopes for the presence of chromatic aberration (a defect that causes light of different colors to focus at different places), I aimed at the magnitude 0 star Vega. While there were some purple fringes around the star's disk, it was well within expectations for the telescopes' aperture and focal ratio. Likewise, Jupiter and the Moon showed surprisingly little chromatic aberration.

I resolved the four individual suns in the famous Double Double quadruple star (Epsilon [ε] Lyrae) with each telescope at 120x. The Phoenix delivered a slightly better image, probably due to the MaxKuei's slight astigmatism. A 7mm eyepiece (69x) revealed both of Jupiter's prominent equatorial belts but little additional detail.

This is not surprising. Neither the MaxKuei nor the Phoenix should be considered a planetary scope. These scopes excel in low-powered star-field views. With that in mind, and with the summer Milky Way coming into view when I conducted these tests, I took each telescope on a tour of some of the finest clusters and nebulae visible. The short focal lengths of these instruments makes them ideal for sailing through the Milky Way's rich star clouds.

I began my journey at two of my favorite summer objects, the Lagoon Nebula (M8) and the Trifid Nebula (M20). In a word: spectacular! Through a 22mm eyepiece (22x), both objects easily fit into the 3° field of view. The view became even better when I added a narrowband nebula filter. The dark lagoon in M8 was readily visible, as were the brightest stars in the nebula's offspring star cluster, NGC 6530. On the other side of the field of view, the soft light from the Trifid was also unmistakable. I could even make out subtle hints of the criss-crossing ribbons of dark nebulosity that give the object its name.

Scanning westward, the Butterfly Cluster (M6) was also a pleasant sight through these scopes at 22x. The brightest stars unmistakably formed the outline of a butterfly's wings in flight, while fainter suns littered the area with misty starlight. The golden glint from the cluster's lone orange supergiant, BM Scorpii, stood out nicely among the other blue-white points.

Northward along the Milky Way, I visited several deep-sky friends, including the Omega Nebula (M17), the large open cluster IC 4665 in Ophiuchus, the Coathanger asterism (Collinder 399), and the Dumbbell Nebula (M27). The last two lie in Vulpecula. All of these objects are enmeshed within rich star fields and were pleasant sights through both telescopes.

The "Gulf of Mexico" and "Florida panhandle" portions of the North America Nebula (NGC 7000) in Cygnus were both easy to pick out at 22x once I added a nebula filter. Globular clusters M4, M22, and M13 each looked like a ball of cotton suspended in space, although at 69x, M13 looked grainy because I wasn't using enough magnification. Moving up to 120x resolved the stars. I also saw the subtle smoke-ring shape of the Ring Nebula (M57) with averted vision at 69x.

I enjoyed my low-power voyages across the summer sky with both the MaxKuei and Phoenix refractors. Few things are more pleasant than just kicking back and visually drifting through the Milky Way. If you're looking for a worthy traveling companion that's ready to grab and go at a moment's notice, then the MaxKuei 80HD and the Phoenix 80S are good choices. Don't overdo the magnification, and you're sure to have a pleasant journey. A

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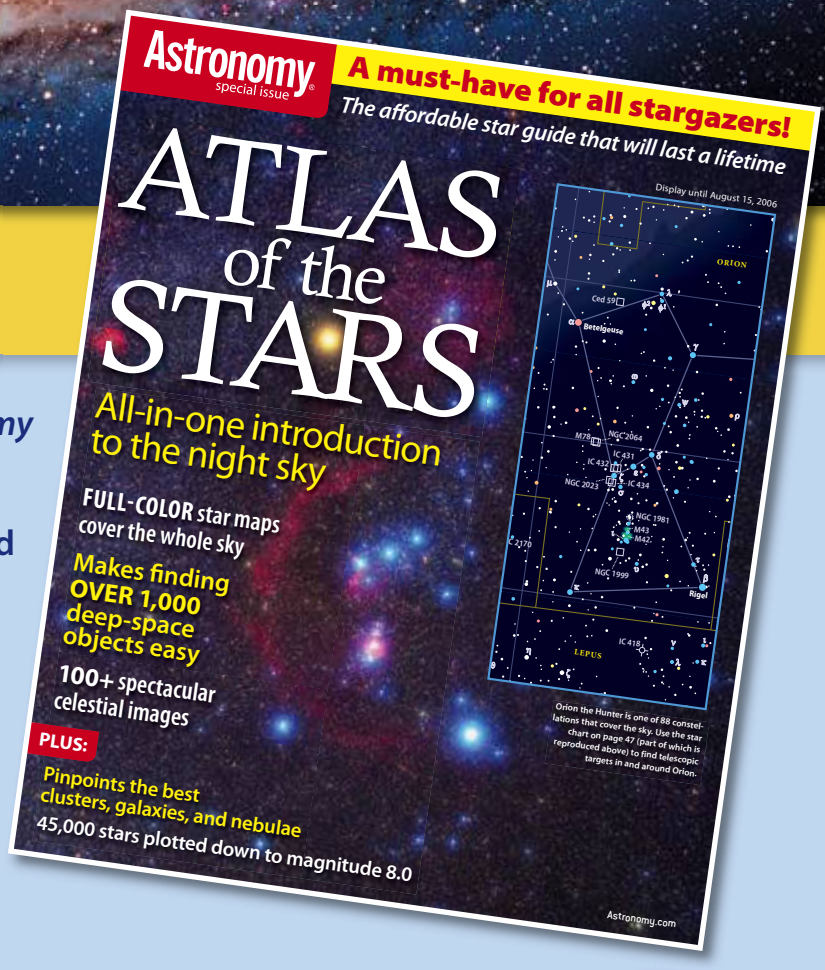

TONY HALLAS

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C8-N 8" Newtonian....699.00
C10-N 10" Newtonian....909.00
C9¼-S 9.25" SCT....1469.00
C11S-SGT w/XLT (SCT)....1977.00

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New C100 ED Refractor....1574.00
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C9¼-S-GT 9¼" SCT....1779.00
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NEW NEXSTAR SLT
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Nexstar 102....479. Nexstar 114....399.
Nexstar 130....439.

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MARCH 16–18, 2006

Reckless use of lights has destroyed

the night sky in many communities. Founded in 1988, the International Dark-Sky Association (IDA) offers solutions for intrusive lighting and energy waste. If you'd like to fight light pollution, venture to the IDA

IDA

LIGHT POLLUTION continues to be a problem for all observers. In this image, you can see its influence across the United States. In metropolitan areas, many features of the night sky have vanished from sight.

annual convention in Tucson, Arizona. Architects, designers, psychologists, lawyers, and other professionals will present ideas to support the effort.

For more information, call the IDA at 520.293.3198; web site, www.darksky.org.

MARCH 1–5
Kisatchie Star Party
Kisatchie National Forest, Natchitoches, Louisiana. This remote site guarantees a dark sky. Non-astronomy activities include camping, hiking, canoeing, and fishing. For more information, visit www.bro.lsu.edu/bras/kisatchie.html.

MARCH 3
Far Out Friday
Adler Planetarium and Astronomy Museum, Chicago. On the first Friday of every month, the Adler hosts an evening of astronomy-related fun, including observing, lectures, planetarium shows, and tours of the facilities. For more information, call 312.922.7827; web site, www.adlerplanetarium.org.

MARCH 3
Tri Star
Guilford Technical Community College, Jamestown, North Carolina. Cosponsored by the Cline Observatory and Greensboro Astronomy Club, this event features speakers, prizes, and vendors. For more information, visit technet.gtcc.cc.nc.us/comserv/cline.

MARCH 4
Wagman Winterfest
Wagman Observatory, Deer Lakes Park,

near Russellton, Pennsylvania. Hosted by the Amateur Astronomers Association of Pittsburgh, this event is free and open to the public. If you are in the market for a new telescope, Winterfest experts will help you find the perfect match. For more information, call Pete Zapadka at 412.487.9363.

MARCH 10–13

Mid-Florida Star Gaze

Kye Ewing's Star Farm, near Venus, Florida. The Astronomical Society of the Palm Beaches will host this sixth-annual event under dark skies. For more information, visit www.palmbeachastro.org.

MARCH 11–12

Kitt Peak National Observatory CCD Workshops

Kitt Peak National Observatory, Tohono O'odham Reservation, Arizona. Learn how to produce stunning images of deep-sky objects. These workshops cover many topics, including basic equipment setup, problem solving, and obtaining the best results. For more information, call Robert Wilson at 520.318.8440; web site, www.noao.edu.

MARCH 17–19

Mid-Atlantic Mirror-Makers Weekend

St. Jones Reserve, Dover, Delaware. This seminar will introduce novices to mirror-making techniques and practices. Emphasis will be placed on figuring the mirror. All materials will be furnished, and expert mirror-makers will help guide each person's activities. Attendees will leave the weekend with a fine-figured mirror ready for aluminizing. They will also know how to repeat the process. For more information, visit www.delmarvastargazers.org.

MARCH 24–26

Spring Equinox Star Party

Kelling Heath, Norfolk, United Kingdom. This event is held at a particularly dry site for the region. When not observing, you can visit one of the many museums in greater Norfolk. For more information, visit www.starparty.org.

MARCH 25

All Arizona Messier Marathon

Farnsworth Ranch, near Arizona City, Arizona. Sponsored by the Saguaro Astronomy Club, this event begins in the early evening and will last through the night. See how many deep-sky gems you can spy before sunrise. For more information, visit www.saguaroastro.org.

MARCH 31–APRIL 2

South Pacific Star Party

Wiruna, near Ilford, New South Wales, Australia. The star party is hosted by the Astronomical Society of New South Wales. The dark-sky location is a nature-lover's paradise, featuring many wombats, kangaroos, exotic birds, and other wildlife. For more information, e-mail secretary@asnsw.com; web site, www.asnsw.com/spsp.

MARCH 31–APRIL 2

Tennessee Spring Star Party

Fall Creek Falls State Park, Pikeville, Tennessee. This beginner-friendly star party is free and open to the public. Surrounded by a large nature preserve, this dark-sky site should provide quality views. For more information, e-mail Scott at spsmith@bellsouth.net; web site, www.cumberlandastronomicalsociety.org.

APRIL 20–23

Georgia Sky View

Indian Springs State Park, Jackson, Georgia. This annual event, hosted by the Flint River Astronomy Club, is the premier star party for Atlanta-based skywatchers. With attendance limited to 150 people, be sure to register early. No walk-ins will be admitted. For more information, e-mail sdknight@flintriverastronomy.org; web site, www.flintriverastronomy.org.

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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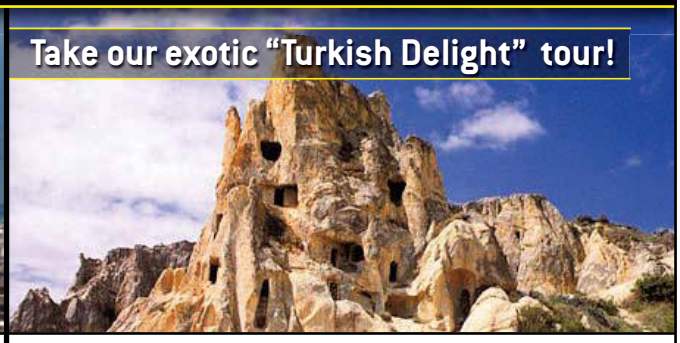

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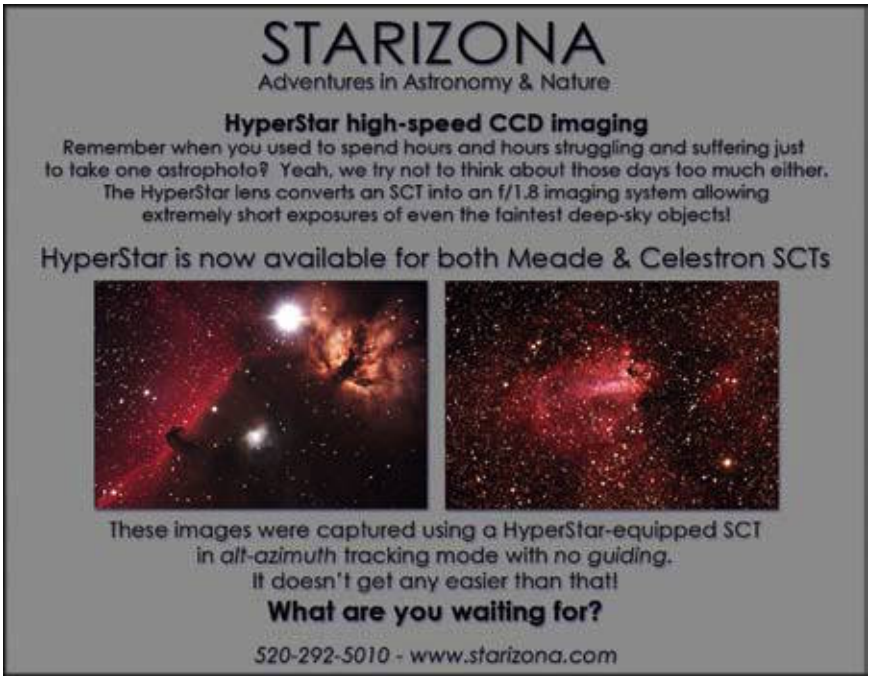
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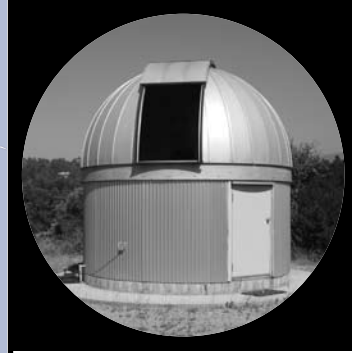
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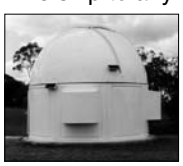

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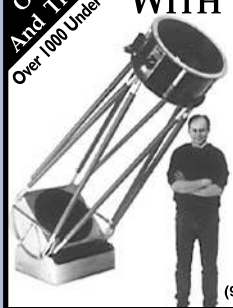

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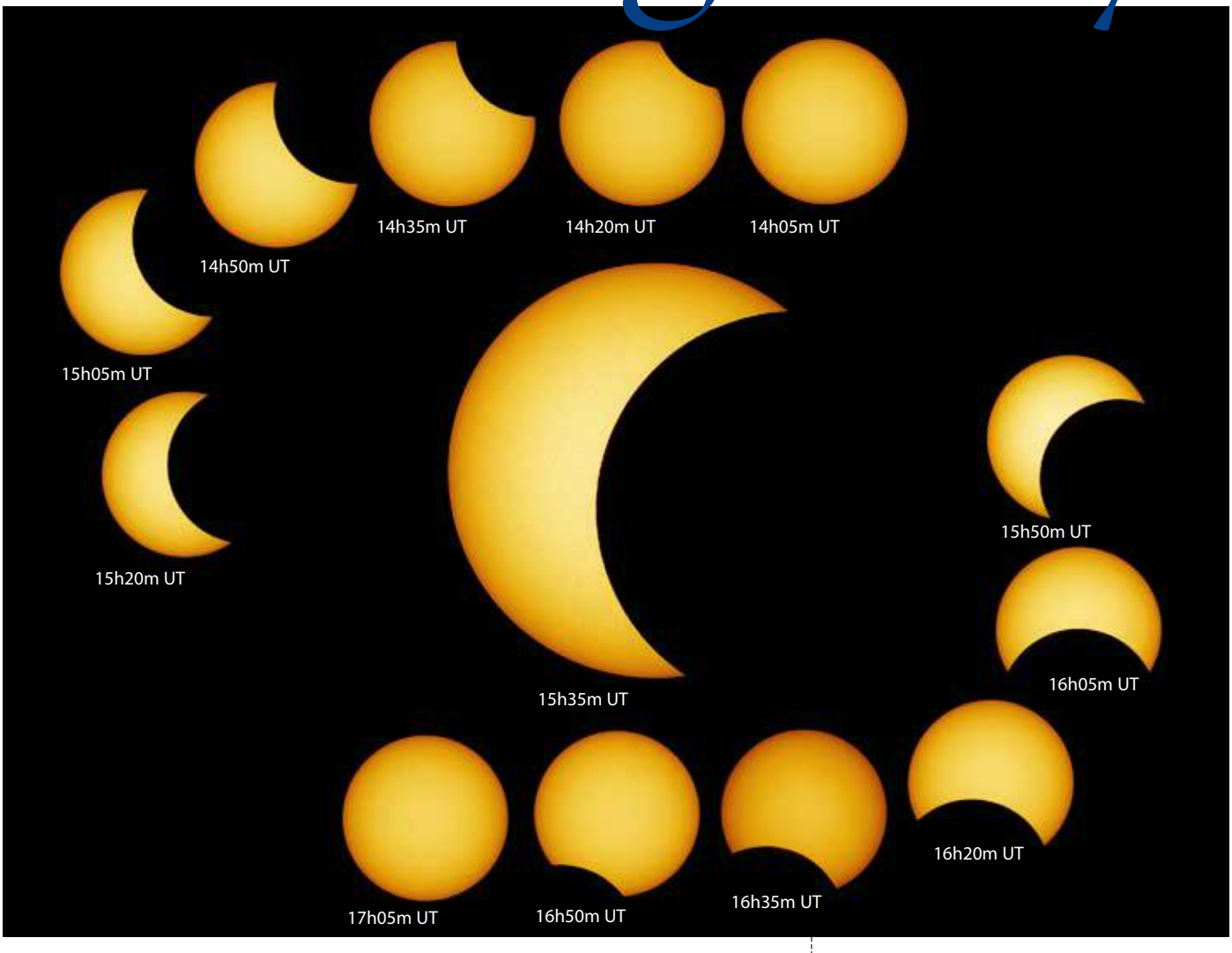
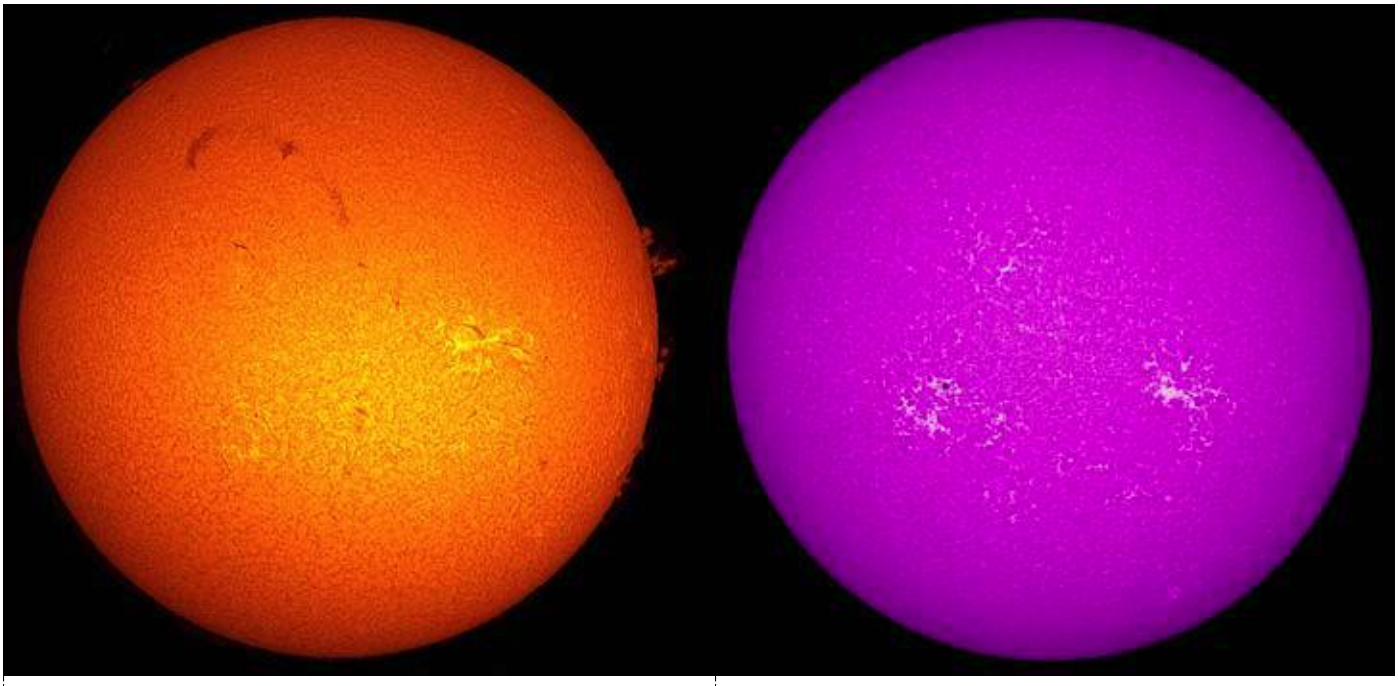


CELESTIAL GEOMETRY

A partial solar eclipse

Solar eclipses have been regarded as mystical since humans started to become aware of the environment. The fact that the Sun's diameter is 400 times larger than the Moon's is balanced by the Sun's distance from Earth — roughly 400 times farther than the Moon. As a result, their diameters appear similar. During a solar eclipse, the Moon lies between the Sun and Earth, an event that occurs about 70 times per century. Sometimes, the eclipse is total. At other times, a fraction of the Sun's disk is hidden.

ECLIPSE SEQUENCE (6.2-inch Astro-Physics Starfire EDF apochromatic refractor at f/7.5, Canon EOS 300D digital SLR, ISO 100, Baader ND-5 solar filter, 1/500-second exposure taken every 15 minutes October 3, 2005, from 14h05m to 17h05m UT) /// **ANTHONY AYIOMAMITIS, ATHENS, GREECE**



A HYDROGEN-ALPHA (Hα) filtered view of the Sun is one we've become accustomed to. The Hα view shows the Sun's chromosphere (a layer beneath the visible disk we see) and also prominences along its edge. (0.5A SolarMax 90 telescope, SBIG ST-2000XM CCD camera, .08-second exposure, taken September 1, 2005, at 17h14m UT) /// **GREG PIEPOL, ROCKVILLE, MARYLAND**

THE CALCIUM K (CaK) line is one of the Sun's strongest spectral lines. A filter that allows only CaK light through reveals a deeper, cooler layer than the chromosphere and shows the Sun's magnetic field lines. (SolarMax 70 CaK telescope, SBIG ST-2000XM CCD camera, .08-second exposure, taken September 1, 2005, at 17h27m UT) /// **GREG PIEPOL, ROCKVILLE, MARYLAND**

REFLECTION NEBULA VAN DEN BERGH 158 lies in Andromeda. Dust — which scatters starlight — forms the main component here, so VdB 158 looks blue and not red. (10-inch Astro Systeme Austria Astrograph at f/2.2, Starlight Xpress SXV-H9 CCD camera, LRGB image with exposures of 70, 35, 35, and 35 minutes, respectively) /// **GERALD RHEMANN AND MICHAEL JÄGER, VIENNA, AUSTRIA**

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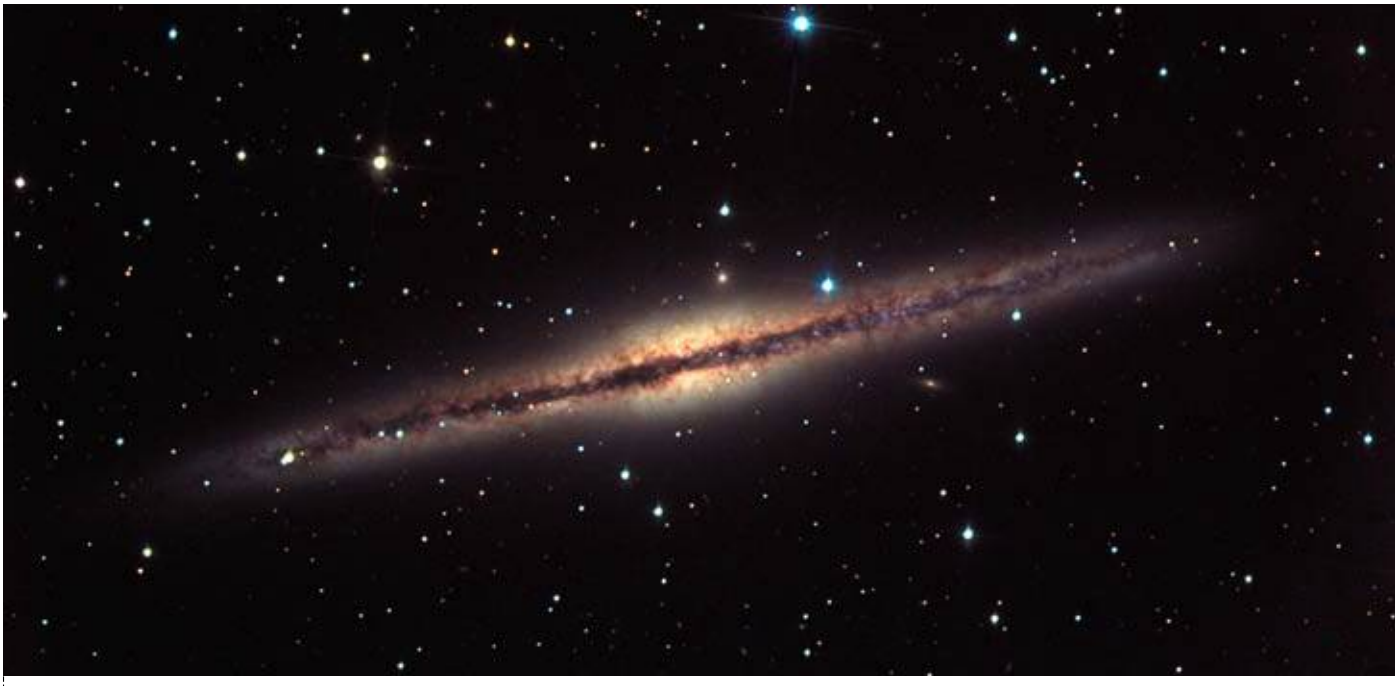
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

OPEN CLUSTER M52 lies a bit more than 0.5° northeast of the Bubble Nebula (NGC 7635). The cluster lies 5,000 light-years from Earth and shines at magnitude 7.1. The Bubble Nebula lies more than twice as far away and is difficult to see in all but the largest amateur telescopes. (4-inch Takahashi FS102NSV apochromatic refractor at f/8, SBIG ST-10XME CCD camera, RGB image composed of ten 3-minute red, ten 3-minute green, and twenty 3-minute blue exposures) /// **DEAN ROWE, CONIFER, CALIFORNIA**



EDGE-ON SPIRAL GALAXY NGC 891 in Andromeda lies 10 million light-years away. Through an 8-inch scope, you'll spot the dust lane splitting it. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.8, SBIG ST-10XME CCD camera, LRGB image with exposures of 120, 20, 10, and 20 minutes, respectively) /// **ADAM BLOCK/NOAO/AURA/NSF, KITT PEAK NATIONAL OBSERVATORY**

THIS NEBULOUS COMPLEX in Sagittarius lies 1.5° east of the Lagoon Nebula (M8). Emission nebulae intermingle with dark nebulae. (6.2-inch Astro-Physics 155 EDF apochromatic refractor at f/7, SBIG ST-10XME CCD camera, Hα/R/RGB image with exposures of 120, 60, 35, 35, and 45 minutes, respectively) /// **THOMAS V. DAVIS, INKOM, IDAHO**

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The Rosette Nebula. Image by Matt Taylor. 15 panel mosaic, 1 hour per panel (6 frames x 10 min. each), 80mm refractor, Meade Deep Sky Imager PRO II.